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CASEM - A SYSTEM FOR
COMPUTER AIDED SELECTION OF ENGINEERING MATERIALS

A THESIS

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CASEM — A SYSTEM FOR

COMPUTER AIDED SELECTION OF ENGINEERING MATERIALS

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SUMMARY

The principal objective of this work has been to develop a computer-oriented pilot system for the selection of the most suitable material for a given design case.

Special emphasis has been placed upon the means of creating a well organized materials catalog from which the selections can be made. The numerical values for various properties and the order of importance of relevant properties (as designated by the designer who is requesting the selection) are the bases of comparisons.

Properties defined as "Secondary" for the purpose of this pilot study are qualitatively rated on a scale of ten for the want of a better basis of comparison. The lack of uniformity in test data or the total lack of quantitative data on such properties is mainly responsible for such a loose basis of comparison.

The main conclusion reached as a result of this study is that the cataloging and selection system presented here in detail can be implemented nationwide with the cooperation of the materials manufacturers and users through a universal clearing house.

The following conclusions and recommendations should also be considered for further development:

1. Further work in this field is necessary, desirable, and justified. The system presented in this study should be improved upon by extending the materials data catalog and by reducing the Input/Output and processing times through program refinements.

2. To simplify comparisons between materials of different nature, the data pertaining to the properties of engineering materials should be made uniform by the use of compatible units. By establishing uniform test conditions for high-temperature properties, creep, corrosion, and the like, these can be included in the compilation of the catalog, and the use of ratings can be eliminated.

3. Today, the selection of a particular material in a given design situation is largely based on the experience of the individual designer and his access to a large, up-to-date catalog library. Therefore, in most cases the decisions are based on a limited variety of materials resulting in costly changes during the production phase.

4. At present the dissemination and maintenance of specific data on engineering materials is done by distribution of catalogs, bulletins, and leaflets published by the manufacturers. Therefore the users have to go through the costly process of maintaining a huge library of catalogs or several such libraries, when the design efforts are decentralized. These disadvantages can be eliminated with this proposed system by the propagation of mass-produced punched cards and/or magnetic tapes. The recent developments in time-share techniques and peripheral equipment make it possible to reach a catalog in a central computer from distant locations by remote terminals through telephone data lines.

CHAPTER I

INTRODUCTION

In a broad sense an engineering material is any physical substance from which a finished product can be manufactured, fabricated, or constructed to serve a pre-defined purpose. Thus, the common volcanic rocks from which mankind's first wheel and first weapons were made, and tropical tree limbs from which the first bow and arrows were made, qualify as engineering materials as well as today's powder metallurgy mixtures and composite materials. However today, in an age when mankind's needs are incomparably more sophisticated in quality and huge in quantity, a narrower more practical definition is necessary. Therefore, specifically, an engineering material is a substance from which an item in demand can be competitively produced.

The value of an engineering material is highly relative, depending on the specific circumstances under which it is to be used. A statement such as "Steel is the most adaptable material," and "Cast iron is the cheapest material" are blanket statements irrelevant to a good design engineer. There are as many different materials suitable for a given design as there are different designs to accomplish a certain design goal. However, there is a "best" material for a certain design when a sufficient number of conditions are set for the material to meet. Consider a simple cylindrical connecting rod to be used in a four-bar linkage. When no conditions are set, a wooden pole with a knot-hole at each end is just as good as a machined steel bar or any other material for that matter. In short, there are an infinite number of materials suitable for this application. However as more conditions are introduced, the selection narrows down. One basic condition almost universal to all design situations is "low cost" which in general applies to the material as well as the other design variables. Another condition is derived from the fact that this hypothetical linkage is to be used in an airborne application and will be subject to high bending loads: the requirement for a high specific strength. It is obvious that an infinite number of conditions such as the two above, can be set to finally limit the choice of available materials to a small number. In most cases however, it becomes necessary to make compromises from the requirements at this stage to reach a definite decision. This is only possible by setting relative priorities for each requirement; i.e., "what is the most important requirement?", "second most?", etc. and then comparing each material successively with others in view of requirements and priorities.

It is apparent from this short discussion that a theoretically ideal material selection which starts from an infinite number of available materials and proceeds with a large number of requirements and their assigned priorities, suggests a lengthy, time consuming process of successive comparisons. In actual practice such a long, uneconomical process is avoided by limiting the number of materials available to those with which the designer has previous experiences and/or those used for similar applications in the past. Requirements are also limited to a few that have the highest priority, i.e., the most important ones.

The rest is left to be decided by costly trial-and-error methods that quite successfully indicate critical shortcomings in tangible properties such as strength, corrosion, etc., but fail to indicate any intangible disadvantages such as the high cost, low specific strength, etc.

Developments in the last 30 years in several fields made a systematic approach that more closely approximates the theoretically ideal material selection, both necessary and possible. These developments are:

a. Unprecedented expansion of technical and scientific information. It is estimated that scientific and technical information has doubled every 12 or 15 years since 1750. In the field of engineering materials the growth of information is at least parallel to this, if not more accelerated. The 1962 edition of the Materials Handbook issued by the Materials in Design Engineering (4)* has only less than 200 pages in comparison with more than 550 pages of materials data in the 1965 edition (5). A close look at the latter also reveals that, during the year 1965 only, information became available on ten new irons and steel; 15 non-ferrous metals; 24 plastics and rubber; nine ceramics, glass, carbon, and mica; five fibers, felts, wood, and paper; and 12 composite materials, in addition to new data on more conventional materials and their variations. The first volume of the Metals Handbook prepared by the American Society for Metals (6), has expanded threefold from the seventh edition to the eighth. Other facts pointing at the

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*Numbers in parentheses refer to items cited in Bibliography.

information explosion specifically in the field of engineering materials are too numerous to list. The inescapable conclusion is that all these data should be systematically organized for easier access, wider use, better cataloging, and wider dissemination (1,2,3).

b. Development of automatic data processing devices and the birth of the information science. Three principal reasons, namely emergence of statistics as an important tool in economics; fast rising costs of labor; and industrialization, gave way to the development of electronic data processing equipment (7). Extensive developments in the computer technology in a short period have made the multi-purpose computers and the smaller, cheaper limited-purpose computers a standard tool of management and engineering (8). The formulation of time-sharing systems and the emergence of data processing service companies have brought the computers into the reach of even the smaller engineering companies (9). It is only natural to deduce that computers should be utilized to bring comprehensive materials data within reach of every engineer to the benefit of both the users and the manufacturers.

c. Emergence of operations research as an important branch of applied science. Operations research was born during the Second World War in response to military logistics problems. However, its techniques are being widely used today in industrial management to improve decisions, scheduling, queuing, stocking, and many other management functions (10). Mathematical development of the statistical decision theory is one of its many contributions and it applies equally well to engineering decisions as it does to management (11).

One of the basic decisions that a design engineer faces frequently is the selection of a material suitable for the manufacture of a part under consideration. In view of the trends above, it is logical to assume that a system can be devised to develop and maintain a well organized, extensive materials catalog and to select the most suitable material for a given design situation by utilizing the mathematical decision theory together with the computational speed and huge memory capacity of the electronic computers. This, then, is the principal object of this pilot study.

CHAPTER II

ENGINEERING MATERIALS AND THEIR PROPERTIES

A Brief Look at the Present Status and the Future

Materials

A very rapid and accelerated development of new engineering materials occurred during and in the years following the Second World War. During the war, most publicized developments were in the light metals, and in plastics and synthetics. However, the necessity of conserving scarce raw materials also led to revaluation and improvements in older materials (12).

After the war, the impact of the theories developed in the 1930's in the basic sciences became increasingly more pronounced. The entire picture of the subatomic structure of matter was revolutionized by the development of quantum mechanics. The studies of crystal defects, the development of a dislocation model for plastic flow, and the studies of diffusion were advances so revolutionary that it was only a question of time until the field of materials would begin to feel the impact (13).

To be sure, the engineers of the Pharaohs erected marvelous buildings three thousand years ago, with no power except that of men and animals, and virtually no materials except stone, brick, and gypsum plaster. They also built carriages made of only wood and leather. The situation changed very little until the nineteenth century.

This extraordinarily slow progress was not completely due to a lack of mental ability on the part of the engineers all through the centuries, but partly due to a lack of suitable materials with which to work. The idea of the steam engine had been in men's minds for centuries, but it took 25 years and one of the best machine builders in Great Britain for James Watt to build an engine that would function satisfactorily. His inventive genius could design governors, linkages, and gears, but he could not obtain a true cylinder or a tight piston. When he did obtain a cylinder only an eighth of an inch larger at one end than the other, he hailed it as a triumph. Due to the lack of heavy rolling mills, the only sheets available for boiler manufacture in Watt's days were of wrought iron. The whole development of steam power had to lag until large machine tools could be built, and these tools had to await the production of large ingots of steel, and large ingots of steel were unknown until Bessemer invented his steelmaking process in 1856.

The impact of the developments between the First World War and the Second came in the late forties and early fifties in the form of better alloys, improved properties, and composite and reinforced materials. Airplane, space, and weapons technologies, coupled with unprecedented economic expansion and prosperity, both benefited from, and forced, the development and widespread use of new materials and alloys. Mass-produced aluminum, magnesium, and titanium alloys, powder metallurgy, refractory metals, superalloys, coated and high-strength steels, are all answers developed in response to requirements imposed by these technologies.

The nonmetallic materials, responding to the expanding economy and consumer prosperity, have exploded into the marketplace. Polymers and their blends, ABS/PVC thermoplastic sheets, and other conventional mill forms, structural foams, fiber glass, phenolics, polyesters and numerous other thermosets, elastomers, new ceramics, carbons and graphites, are not only replacing conventional materials, but also are finding imaginative uses no one would have expected 20 years ago.

In any field changing as fast as the field of engineering materials does, it is highly desirable to take the time to review the status of various areas before any projections into the future are made. The following, then, is a snapshot of this field, assessing the present status and the future of each area.

Steel. Today steel is available in a wide range of alloys and a variety of mill forms. The amount of information gathered in alloying and manufacturing steels in most applications is so detailed that it is almost possible to custom make alloys for specific products. Because of this, most of the developments should be expected in the improvement of mill methods, heat treatments, and further specialized areas of coated steels, P/M products, etc.

Superalloys. Development of superalloys that withstand high loads at high temperatures have made space re-entry vehicles, supersonic aircraft and rocketry, and gas turbines possible. New developments in these nickel-, and cobalt-based alloys and titanium are most likely to be in the methods of production and in the improved stress-corrosion characteristics.

Copper. The use of copper for applications requiring high rates of heat transfer and electrical conductance together with strength is being challenged by aluminum and other light metals readily available in materials markets. The diminishing supply and the resulting higher prices are forcing the users to look for substitutes. So the future developments are most likely to be in the improvement of these properties together with new and better reclamation processes. Developments in newer and cheaper bearing alloys are also probable.

Light Metals. The use of magnesium in space applications has increased tremendously in recent years. Because of the very high specific strength it possesses, its use should continue increasing and trigger further developments in both the manufacturing processes and improved properties.

Aluminum use should continue to grow and spread further into new areas such as bearing alloys, electronics, composites, etc. The most important future development will probably be in the improvement of its stress-corrosion resistance without sacrificing strength.

Refractory Metals. Columbium, tungsten, and tantalum alloys are presently being used in aerospace applications and weapons systems. Future developments should be in the direction of improved stress-rupture strength, better oxidation resistance, refined heat treatments, and production innovations.

Powder Metallurgy. This relatively new technique is gaining widespread use in replacing conventional casting and forging processes because of its advantages of increasing ductility and improving properties. Its versatility in obtaining custom-tailored properties through the manipulation of blending ratios and compacting density, and the possibilities it offers in blending metals with nonmetallics, are virtually endless. Future developments, obviously will be in providing a wider range of powdered materials (possibly superalloys) as well as improved blending and forging techniques.

Plastics, Rubber, and Ceramics. With the continuing trend of decreasing prices, thermosets and thermoplastics have invaded the markets that traditionally belonged to paper, wood and other organic materials, and lower priced cast metals. They are everywhere; from products for the home to automobiles, to industrial products. Developments in the near future are more likely to be in novel applications and custom-tailored properties rather than new compounds. Important developments will probably also unfold in reinforcing and plating techniques in an effort to open new markets as substitutes for higher priced metals.

Elastomers have come a long way from natural rubber. Synthetic manufacturing methods coupled with chemical post-curing and hardening techniques are producing elastomers that respond to classical applications better. Improvements will probably be in the direction of more economical production methods as well as improved extreme temperature characteristics.

Probably the most significant trend taking place in ceramic materials is their growing use in many new applications. New uses are being found in chemical processing, automotive, appliance, and electrical and electronic equipment where maintenance-free, long lasting usage is made possible by the outstanding oxidation and corrosion resistance, dimensional stability, and heat resistance qualities of ceramics. Developments in the near future will have to be oriented toward individual applications.

Other Materials. Most of the other materials such as fibers, felts, wood, paper, carbon and graphites, rare metals, etc. have all shown improvements in production methods and/or mechanical and physical properties. But these improvements mostly have been geared to individual applications in recent years, and there is no reason to think that it will be different in the near future.

In this continuous interaction of sociological, economical, and technological activities, new trends inevitably mean new and improved materials and methods. It is not very hard to project that the dawning ecological renaissance will no doubt re-direct at least some of the efforts toward reclamation processes and reusable rather than disposable materials. Precarious prices and supplies in the world market for metals such as nickel, chromium, and cobalt are already pushing the manufacturers toward the development of substitute materials and new designs using other materials. New technologies such as cryogenics, nuclear power, underwater research, off-shore mining, and space exploration do and will continue to require materials with extreme properties that were hitherto unnecessary. Answers to these challenges will be provided by new materials as well as new production methods such as reinforced materials, composites, powders, whiskers, finishes, and coatings, etc.

Properties

A quantity that defines a specific characteristic of a material is a property. The properties of a material provide a basis for predicting its behavior under various conditions (14). Materials properties commonly used in engineering design can generally be classified into five major groups: mechanical (strength, etc.), physical (density, electrical and thermal conductance, etc.), chemical (corrosion resistance, etc.), technological (machinability, etc.), and composite properties (specific strength, etc.).

If a property is to be used as the basis of comparison between different materials, obviously the method with which it is evaluated must be standardized. Until recently this standardization was usually undertaken by either the users or the manufacturers, and often by both. A healthy trend in the sixties, however, has been toward the merging of all standard testing specifications into the large body of specifications created and standardized by the American Society for Testing Materials.

The testing methods, and the properties tested, are generally dependent on the particular material group in question because of the different physical configurations, particular range of properties, and the different end uses. For example, the bursting strength for polyethylene films and shear strength for cast steels are generally known properties, but bursting strength for cast steel and shear strength for polyethylene film would not only be useless properties but also meaningless. Therefore, a preliminary comparison of the materials has to be made based on the intrinsic qualities of their general classes. A quantitative comparison between different classes is often not feasible and is usually unnecessary, except in extreme cases. One must be very careful in interpreting and comparing property test results for different materials even within the same general class. Test methods will often change to accommodate widely varying ranges in the value of the property and the physical limitations imposed by the materials themselves. For example, tensile strength is evaluated by ASTM D882 for polyester films, but for woven glass reinforced polyester fabric the method generally used is ASTM D638. Corresponding values of the tensile strength are 17-18 ksi and 25-55 ksi, respectively.

A good understanding of definitions of various properties is usually the first requirement toward correct interpretation of the values determined by tests. Therefore, it is appropriate to outline the definitions of the properties used in this study (6,15).

Tensile Strength. Under tensile testing conditions, the ratio of the maximum load to the original cross-sectional area. This is also called the "ultimate strength."

Yield Strength. The stress at which a material exhibits a specified deviation from the proportionality of stress and strain. An offset of 0.2 percent is used for many metals.

Shear Strength. The stress required to produce fracture in the plane of the cross section, conditions of loading being such that the directions of the force and of resistance are parallel and opposite, although their paths are offset a specified minimum amount.

Compressive Strength. The maximum compressive stress that a material is capable of developing, based on the original cross-sectional area.

Tensile, yield, shear, and compressive strengths are measured in psi (pounds per square inch) or ksi (1000 psi).

Elongation. In tensile testing the increase in gage length measured after fracture of the specimen within the gage length, usually expressed as the percentage of the original gage length.

Reduction of Area. Expressed as a percentage of the original area, the difference between the original cross-sectional area of a tensile test specimen and the minimum cross-sectional area measured after complete separation.

Modulus of Elasticity. A measure of the rigidity of materials. Ratio of stress, within the proportional limit, to corresponding strain. Usually, unless otherwise specified, it refers to the Young's modulus, obtained in tension or compression, measured in psi or ksi.

Endurance Limit. The maximum stress below which a material can presumably endure an infinite number of stress cycles. Also called "fatigue limit" and measured in psi or ksi.

Brinell Hardness. Resistance of metal to plastic deformation by indentation as measured by the Brinell method.

Machinability. The relative ease of machining a metal. Usually expressed on a scale where AISI B1112 steel is assumed to have a machinability of 100.

Density. Weight of material per unit volume, measured in pounds per cubic inch.

Electrical Resistance. The property of material which determines the amount of current produced by a given difference of electrical potential. Usually used to mean the specific electrical resistance, which is the resistance of the unit volume expressed in ohm-cm or microohm-cm.

Melting Point. The temperature at which a pure metal, compound, or eutectic changes from solid to liquid; the temperature at which the liquid and solid phases are at equilibrium. Measured in degrees Fahrenheit (°F).

Thermal Conductivity. Time rate of transfer of heat by conduction, through unit thickness, across unit area, for unit difference of temperature. Measured in British thermal units per hour per square foot of cross-sectional area for a thickness of one foot and a temperature difference of one degree Fahrenheit (BTU/hr/sq.ft/°F/ft).

<u>Thermal Expansion</u>. The ratio of the change in length of a material due to heat input for a change of one degree Fahrenheit in temperature, to the original length measured at 32°F.

<u>Composite Properties</u>. Combination of two or more basic properties. Those used in this study are specific stiffness and specific strength which are obtained by dividing the modulus of elasticity and the yield strength by the density. Also used are stiffness price and strength price obtained by dividing the same properties by the comparative price per pound.

Obviously, there are many other properties that play important roles in the selection of materials in various design situations, but neither the scope nor the purpose of this pilot study would permit the inclusion of these. Properties included here, however, should be sufficient to demonstrate how all properties generally affect the decision process as employed in engineering design and materials selection.

CHAPTER III

ANALYSIS OF DECISION PROCESS AS RELATED TO THE SELECTION OF ENGINEERING MATERIALS

Proper analysis of material selection requires an understanding of the logical activities involved in the process of mechanical design. In this chapter, general procedures used in the design of mechanical systems and elements and material selection will be outlined with special emphasis on the methods employed for major decisions throughout the process.

Design Methodology

A review of the literature shows that every author that attempted the task of analyzing the design process concluded with a different set of steps representing the process. These differences, in general, can be attributed to varying past experiences and backgrounds of the investigators. It is obvious that a somewhat different approach would be used in the design of a weapons system as compared to the design of a consumer product. Table 1 shows a comparison of various descriptions of the design process collected by Alger and Hays (16). It can be argued, however, that the differences are generally those of semantics, interpretation, and emphasis rather than basic methodology. Regardless of these variations in emphasis, every successful design effort can be broken down into four main activities:

1. Recognition of a need for a system to perform a certain

Table 1. Various Descriptions of the Design Process

Source A	Source B	Source C	Source D	Source E
Analysis	Recognize	Investigate direction	Recognize	Review requirements
Synthesis	Define	Establish measures	Specify	Brainstorm
Evaluation and decision	Conceive	Develop methods	Propose solutions	Evaluate and analyze
Optimization	Apply	Optimize a structure	Evaluate alternatives	Analyze and refine
Revision	Evaluate	Complete a solution	Decide on a solution	Layout and design review
Implementation	Communicate	Convince	Implement	Details, hardware and manufacturing

SOURCES

A) M. Asimow, "Morphology or Vertical Structure of Engineering Work," Introduction to Design, Prentice-Hall, Inc., Englewood Cliffs, N. J., 1962.

B) Engineering Services, General Electric Company, 1955.

C) E. K. Von Fange, Professional Creativity, Prentice-Hall, Inc., Englewood Cliffs, N. J., 1959, pp. 129-130.

D) J. R. M. Alger, C. V. Hays, Creative Synthesis in Design, Prentice-Hall, Inc., Englewood Cliffs, N. J., 1964.

E) A. E. Coryell, "The Design Process," Machine Design, November 9, 1967, pp. 154-161.

function. This activity includes the definition of basic requirements.

2. Formulation of a feasible concept. This usually involves several cycles through the phases of conceptual design and feasibility determination until a feasible concept is found and/or optimized.

3. Development of the basic concept into a working system. This includes component selection and/or design, if applicable.

4. Production of the developed system. This includes improvements based on the feedback from actual applications.

Often the design process cycles through these steps several times for a single product.

Materials Selection in Design Process

Material selection and evaluation takes place to some extent in all of the above activities, with the possible exception of the first. To reflect that, an analysis of the design process is shown in flow chart form in Figure 1 (17). First encounter with a materials question is generally during the evaluation of feasibility of the tentative concept. Questions to be answered are of a general nature and are mostly concerned with whether or not any extreme material properties would be required. It is at this stage that certain classes of materials are usually eliminated from consideration due to their limitations. Often a tentative decision is made as to the general class of materials to be considered. It is also possible that materials limitations might make it necessary to reformulate the tentative concept and even force modifications in the secondary specifications for the function to be performed.

The most extensive materials evaluation takes place during the development stage. This usually involves the determination of critical

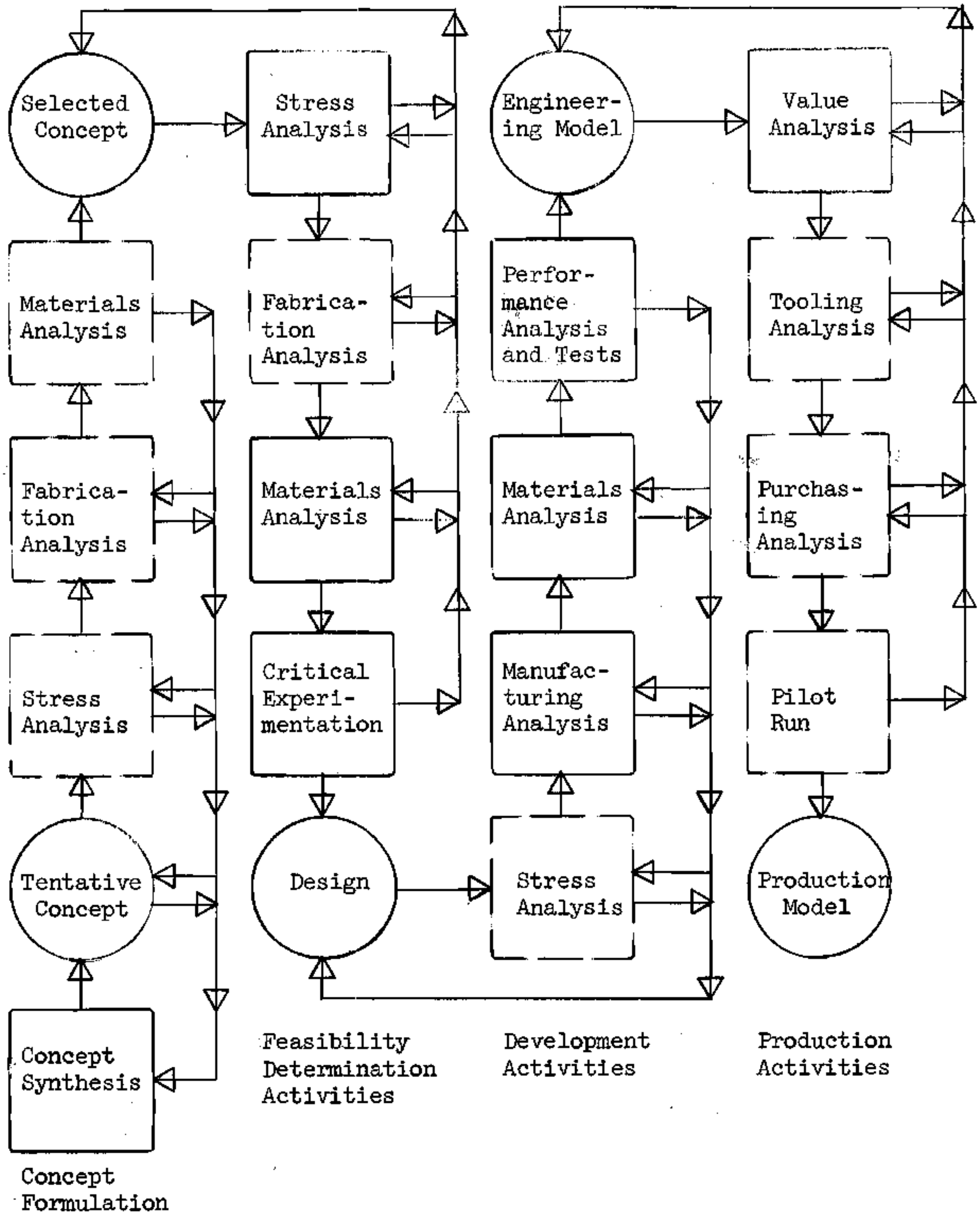

Figure 1. Materials Selection and Evaluation Activities During Design Process

values for various materials' properties, as well as desirable manufacturing methods, allowable costs, availability of standard shapes, and other such factors peculiar to the design problem at hand. These activities are investigated in further detail in the next section.

Materials evaluation also takes place during the production but this is usually of minor importance compared to the activity in the development stage. The occurrence of unexpected conditions in tooling, purchasing, production, or marketing might sometimes cause a major change in material specification, but this generally also requires a redevelopment effort and therefore is the same as the activities associated with the development phase.

Logical Decisions in Material Selection

Material selection in engineering design can be represented as a series of decisions and actions as shown in Figure 2. The process usually starts with a search for previous experience by the designer on similar applications. Availability of direct (2)* or indirect (3) information on such applications either from the designer's own experience or from technical literature provides the starting point, but this also diminishes the possibility of a fresh look at the probable hidden disadvantages such as excessive cost, newly available substitutes, etc. Quite often the matter of possible recent changes is not investigated (11), and response to the question of alternatives (20) is negative.

In the absence of information on previous experience, the next

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*Underlined numbers in parentheses refer to block sequence numbers in Figure 2.

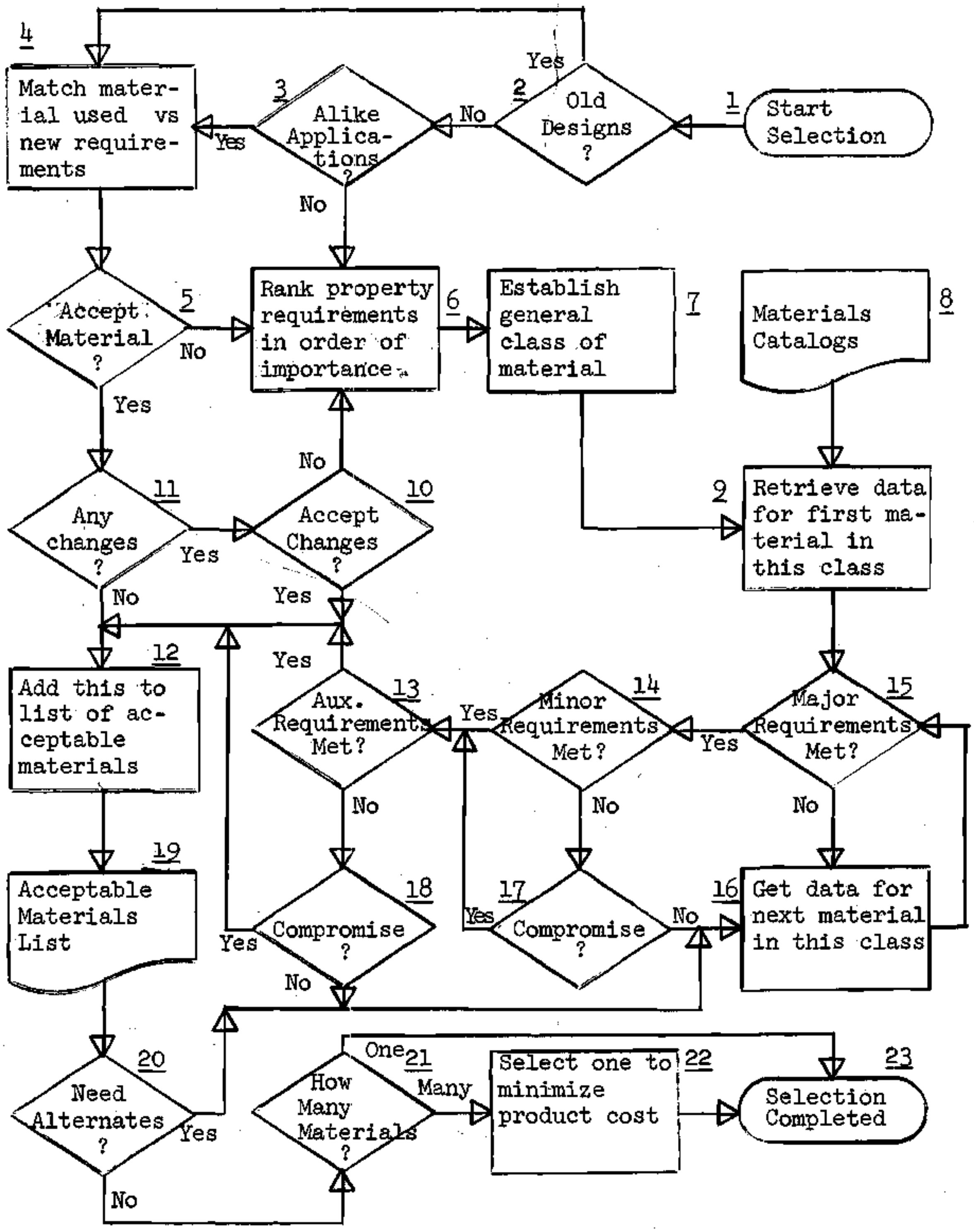

Figure 2. Material Selection--A Simplified Flow Chart

action is an ordering of priorities of various property requirements (6), and (based on the dominant property so determined) the selection of the general class of materials to be considered (7). The latter is bypassed if this determination was made in the feasibility stage.

Following the class determination, a series of comparisons takes place to match the design requirements against properties of each individual material in the selected class. Usually there is no compromise from the major requirement (15). The minimum acceptable numerical value of the property leading the priority ranking has to be satisfied. In addition to that, if optimization techniques are being used, a combination of several properties associated through a design equation must be satisfied. Minor requirements (those that follow the major property on the priority list) can usually be compromised if the situation requires it (14). A considerable amount of flexibility is also exercised in the requirements for auxiliary features such as standard mill forms, availability (lead times), manufacturing methods, etc. (13). If all of these tests are properly passed or compromised, material is added to the list of acceptables for further consideration (12,19). Alternates are added to the list through repetitions of the same process until all likely materials in the selected class are investigated (20).

If there is more than one candidate on the resulting list of acceptable materials, a final elimination takes place based on either the material selection factor (19) (if optimum design methods are employed) or auxiliary requirements such as cost, fabrication methods, etc. (21,22).

It should be emphasized that this picture of the material selection process is simplified to bring out the highlights, and at a given location for a specific design project, there might be variations both in sequence and in importance placed on different steps.

Current material selection process as characterized above has various important drawbacks:

1. Dependence on previous experience hinders the consideration of newer, possibly more suitable, materials.

2. Dependence on proper maintenance and updating of materials catalogs by vendors slows down dissemination of data and limits the materials data available for selection.

3. Compromises are often made on the basis of personal preferences that are not explicitly known or stated.

4. Cost factor is often considered with only a passing interest and has to be reevaluated by value engineering during production stages.

5. Numerical comparisons of properties are made in a sequential manner rather than simultaneously, resulting in uneconomical use of materials with better properties than necessary.

In the following chapter an automated system to minimize these disadvantages will be developed and presented.

CHAPTER IV

DIGITAL COMPUTERS AND DECISION THEORY AS ENGINEERING TOOLS

Digital Computers

In the few years since their development, computers have become important tools in many branches of engineering. Their use in engineering today is incomparably more sophisticated than their humble beginnings as glorified calculators. This growth has been a result of developments in three important directions:

1. Sophistication of physical devices associated with computer systems.

2. Development of advanced compilers, program packages, and programming systems, further facilitating engineer-computer communications.

3. Increasing emphasis with which engineering schools educate students in programming and use of computers.

Many routine computational tasks in engineering have been programmed through the efforts of computer manufacturers, engineering groups of private companies, or educational institutions. Specialized programs are now widely used in many disciplines of engineering. Some specific examples of such programs are:

"SKETCHPAD" (20), a system developed by the Mechanical Engineering Department at the Massachusetts Institute of Technology (MIT), for kinematic evaluation of linkages.

"COMMEND" (21,22), COMputer aided Mechanical ENgineering Design, developed by the International Business Machines Corporation (IBM), for design computations on basic machine elements (springs, gears, etc.)

"STRESS" (23), developed by the Civil Engineering Department at MIT for structural analysis computations

"COGO" (24), COordinate GeOmetry Program for surveying and plane geometry calculations

"DYANA" (25), DYnamic ANAlyzer for analysis of dynamic systems

"ECAP" (37), Electronic Circuit Analysis Program, developed by IBM.

These are some representative examples, the list is too long to include here.

Development of systems and programs for storage, search, and retrieval of engineering information has been much slower. Of the two facets of the information retrieval problem in engineering, one (document retrieval) has received all the attention while the other (data organization and retrieval) has been grossly ignored.

The emphasis on document retrieval has been mainly due to pressure exerted by groups of engineers and scientists alarmed by the information explosion that has been taking place in the last 30 years. First such system of programs to be developed and successfully implemented was in the field of Chemical Research (Chemical Abstracts Search and Retrieval System) which did not lend itself to uniform quantification of standardized data. Since then many such programs have been initiated (26,27,28,29) by private industry but the main thrust has come from the efforts of the Engineers Joint Council (30).

Engineering data retrieval, on the other hand, shows very little development despite the fact that several articles appeared in professional journals since the 1962 Report of the Engineers Joint Council, envisioning and encouraging such systems. As early as 1965, it has been predicted that:

> ...programs will be available to engineers throughout the design process to provide fast and reliable access to frequently used information. The programs not only retrieve information from a file, but select the items on the basis of their match to some specified set of characteristics (22).

A 1966 paper presented to the Design Engineering Conference by Norman E. Cottrell, Director of Documentation Service for the American Society for Metals, stated:

> ...a relatively small number of journals cover the field of engineering materials definitively. Therefore the task of systematically organizing this type of information presents fewer complications than many other fields . . . (1).

These projections and claims are yet to be realized.

Other problems, similar to the material selection problem in nature, have been programmed and are in use in other fields (32,33,34). These are, in general, simple programs matching the required component characteristics to those on a disk or tape file on a go, no-go basis. Since these matches are on a one-to-one basis (i.e., only one match exists for every requirement), sophisticated decision or compromising techniques are not necessary.

In the selection of engineering materials, however, often there is no exact match for the requirements, and a compromise has to be made. In addition, usually many materials exceed the specified requirements and criteria must be developed as bases of decisions. The technique for such a selection is developed from the methods of statistical decision-making and is outlined briefly in the following section.

Statistical Decisions in Material Selection

Bayesian decision rules and their evaluation is a topic of statistical decision theory. For reference purposes, a brief explanation is included in Appendix A on those aspects of the theory that are necessary in the development of material selection criteria.

Development of Selection Criteria

To be able to apply the statistical decision theory to the problem of material selection, it is necessary to develop the desirability and probability matrices (18,35) in terms of materials' properties and design requirements.

Notation. The following notation is developed for a group of m acceptable materials judged on the basis of n properties. $\underline{P}$ denotes the matrix of the numerical values of each property for each material, i.e., element p_{jk} is the numerical value of the j^{th} property for the k^{th} material. $\underline{I}$ denotes the importance vector representing the weighting factors assigned to each property by the designer on the basis of their relative importance for the particular design problem, i.e., i_j is an element of vector $\underline{I}$ and represents the relative importance of the j^{th} property for all acceptable materials. $\underline{R}$ denotes the request vector, similar to $\underline{I}$ with the exception that element r_j represents the numerical value requested by the designer for the j^{th} property. $\underline{V}$ denotes the vector representing elements v_j specified by the designer to indicate the direction of optimization for the j^{th} property. Element v_j can be assigned only two values, zero and one, causing the optimization of the numerical value for the j^{th} property upwards or downwards, respectively. D_k is an index of the computed desirability of the k^{th} material.

Technique of Selection. Assuming that desirability (D_k) of a material k is inversely proportional to the variation of catalog values of its individual properties (p_{jk} where $j = 1,\ldots,m$) from the requested values (r_j); elements of the property matrix p_{jk} can be normalized with the elements of the request vector r_j such that the normalized property matrix $\underline{P}^n$ will have the elements:

$$\frac{r_j - p_{jk}}{r_j}$$

representing the degree of desirability of each property for each material. This normalized property matrix has to be further changed to account for the differences in the direction of optimization. This is done by multiplying each element by $(-1)^{v_j}$. So $\underline{P}^n$ now has elements:

$$(-1)^{v_j}\left[\frac{r_j - p_{jk}}{r_j}\right]$$

and is a fair representation of the desirabilities associated with each material and each property.

Importance vector $\underline{I}$ in this instance is to represent the weighting factors that make up the probability matrix in the classical decision theory. To do that, however, it must be modified so it will fulfill the requirement that the cumulative total probability must be 100 percent.

This can be accomplished simply by dividing each i_j by $\sum_{j=1}^{n} i_j$. But, before that can be done, the following special condition must be considered. To avoid possible overreliance on, and misuse of, subjective ratings (properties for which uniformly reliable numerical data are not available, i.e., corrosion characteristics) and composite properties (not explicitly available to the designer, e.g., specific strength), constant factors of 0.5 and 0.75 have been applied to corresponding elements of the importance vector $\underline{I}$. Since (as will be seen in Chapter V):

$j = 1,\ldots,5$	represent primary properties,
$j = 6,\ldots,9$	represent ratings (0.5 factor),
$j = 10,11,12$	represent composite properties (0.75 factor),

the cumulative total probability is:

$$\sum I = \sum_{j=1}^{5} i_j + 0.5 \sum_{j=6}^{9} i_j + 0.75 \sum_{j=11}^{12} i_j \,.$$

So the normalized importance vector $\underline{I}^n$ has the elements:

$$\begin{array}{rl} i_j / \sum I & \text{for } j = 1,\ldots,5 \\ 0.5 \; i_j / \sum I & \text{for } j = 6,\ldots,9 \\ 0.75 \; i_j / \sum I & \text{for } j = 10,11,12 \end{array}$$

If the technique of statistical decision-making is followed, the desirability ranking D_k of each material would be obtained by multiplying the columns of normalized property matrix $\underline{P}^n$ with the corresponding element of the normalized importance vector $\underline{I}^n$ and finding the sum of the elements on each row. In the classical sense, each sum would then represent the expected "loss" for the corresponding row. For reasons of computational efficiency, however, each element of normalized property matrix $\underline{P}^n$ is subtracted from unity, thus reversing the order of the final ranking of the above mentioned sums. So now these new values do not represent the "loss," but the relative desirability D_k of corresponding material. Hence, the k^{th} material, maximizing the value of:

$$\sum_{j=1}^{5} \left\{1 - \left[(-1)^{v_j} \frac{r_j - p_{jk}}{r_j}\right]\right\} \frac{i_j}{\Sigma I} + 0.5 \sum_{j=8}^{9} \left\{1 - \left[(-1)^{v_j} \frac{r_j - p_{jk}}{r_j}\right]\right\}$$

$$\times \frac{i_j}{\Sigma I} + 0.75 \sum_{j=10}^{12} \left\{1 - \left[(-1)^{v_j} \frac{r_j - p_{jk}}{r_j}\right]\right\} \frac{i_j}{\Sigma I}$$

should be selected as the most desirable material.

CHAPTER V

"CASEM" - A SYSTEM FOR

COMPUTER AIDED SELECTION OF ENGINEERING MATERIALS

System Description

Definition

CASEM is a pilot system for compilation, maintenance, and updating of engineering materials data, and selection of materials from this data-base to fulfill specific property requirements.

Characteristics

The system was designed to have the following characteristics:

1. Appropriate editing of input data
2. An expandable materials catalog
3. Computation of composite properties
4. Procedures for updating and maintenance of materials data catalog
5. Selection process based on statistical decision-making techniques
6. Output to provide flexibility for the designer to exercise his judgment on the final selection
7. Complete listing of the data-base, or listing(s) sorted on the basis of an individual property as requested
8. Program and data on punched cards.

Minimum Computing System Requirements

Computer program associated with the system was implemented on a Burroughs B-5500 computing system. On that basis, the minimum system requirements are: 80-column card reader, 120-character printer, 24 K minimum core storage for program (48-bit words), minimum of two disk-drives, and a COBOL-61 (or higher level) compiler with the Disk-Sort feature.

System Flow Chart

A flow chart showing input, output, and processing activities associated with this system is shown in Figure 3.

Engineering Department Materials Data Coordinator (A)* is the focal point of maintenance and updating activities. Changes to and deletions of the materials already in the catalog and up-to-date catalog listings are all accomplished and obtained through him. As new materials are brought to his attention, he adds these to the catalog using Materials Data Form (C,D) and requests up-to-date listings (B) from the Data Processing Department using the Listing Request Form (samples of all forms are included in Appendix E). Designers (B) can also submit listing requests, but their main use of the system is with the Selection Requests (F). All of these requests are key punched and verified and arranged into the form of an input deck (Figure 6) for periodical runs. Included in the input deck is the complete Materials Catalog Deck (L) as well as the program deck (M). Output (O,P,Q) is distributed to originating parties.

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*Underlined letters in parentheses refer to Figure 3.

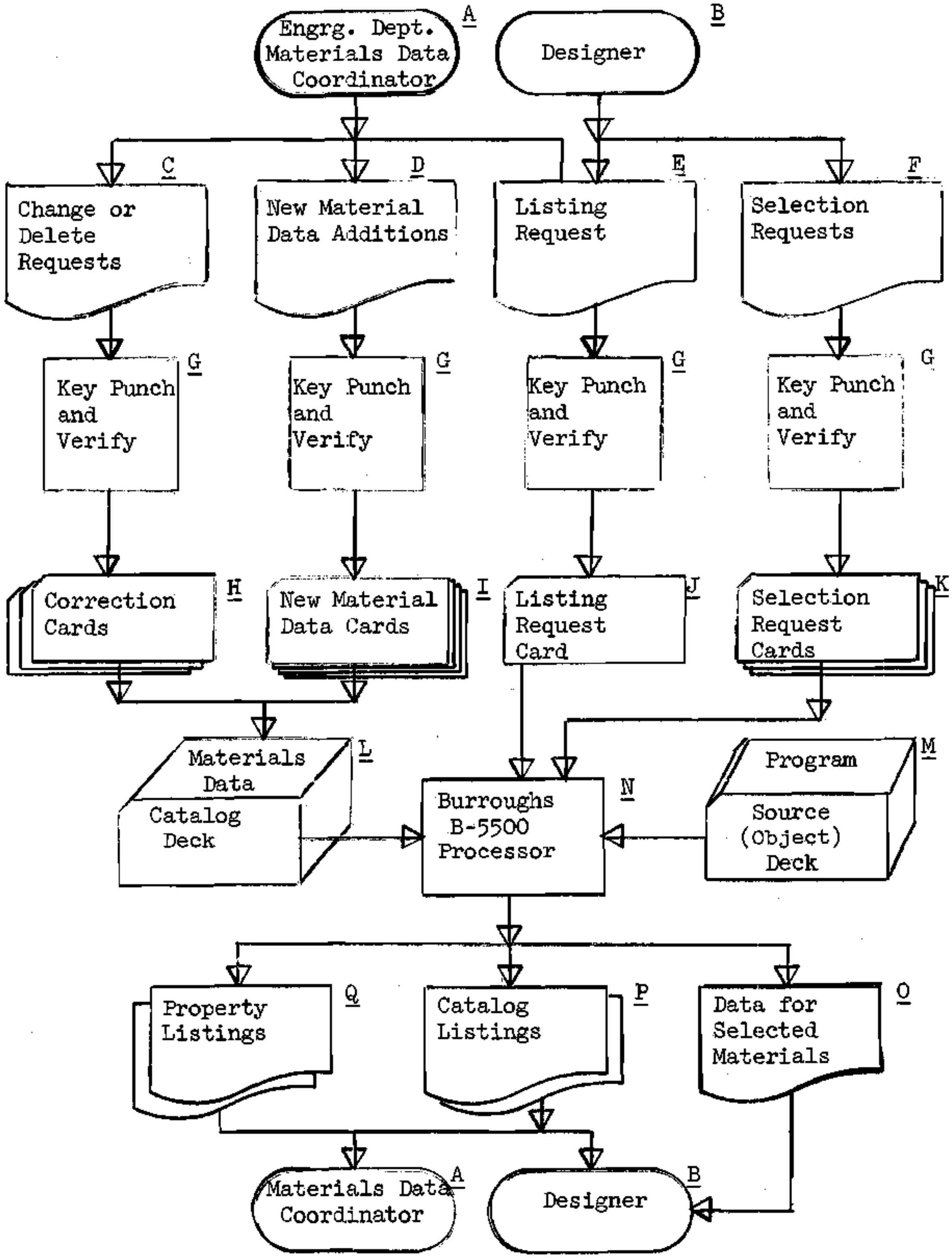

Figure 3. System Flow Chart

Computer Program

A listing of the computer program is included in Appendix D. The program is written in COBOL language because of the relative ease with which literal (alphabetical) data can be handled in this language.

A summary flow chart of inputs to, outputs from, and operations within the program is shown in Figures 4 and 5. First processing activity is reading and editing of all input data (2)* where all sequence and format errors are detected and warnings are printed. If there are no terminal errors (i.e., only card sequence errors), processing continues after discarding all data on the cards with sequence errors. If a listing request was included in the input deck for a complete catalog listing (5), all properties of all materials in the catalog are printed in a tabular form. If there are no other requests (no selections or property listings), the run is then terminated. If there was a selection request (up to nine selection requests can be handled in one run), it is reorganized to indicate properties that are used as bases for selection, and these properties are earmarked for later sorting (6,8). The same process is used to earmark properties for which a property listing is requested (6,10). In either case, the first property that needs to be sorted is determined (9 or 11) and sorted (12). If there was a selection request using this property, then the first ten materials fulfilling the requirements set forth in each request are determined from the sorted list and are added to a list of possibly acceptable materials for that request (14,15). If there was a listing

*Underlined numbers in parentheses refer to Figures 4 and 5.

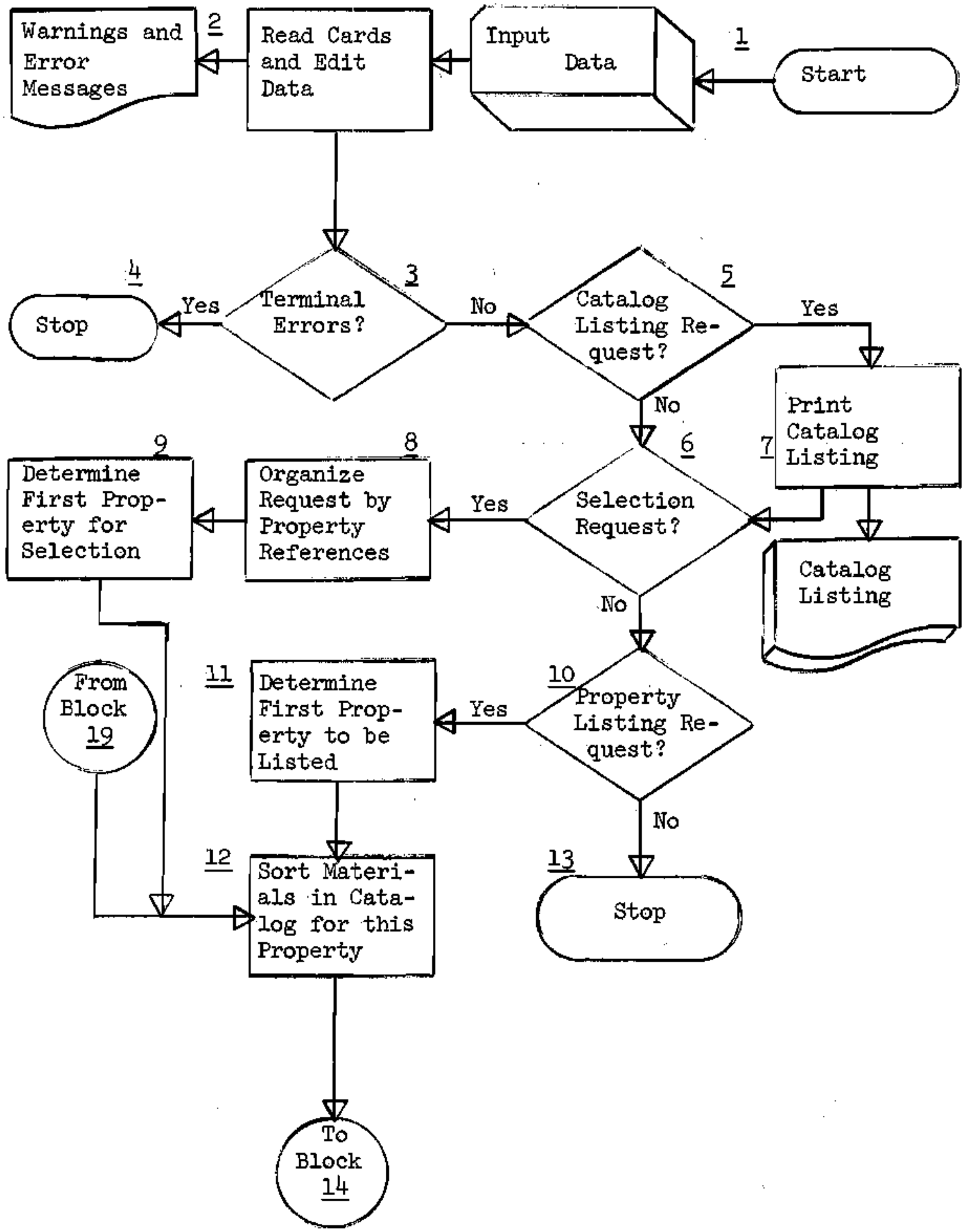

Figure 4. Program Flow Chart
(Continued on Figure 5)

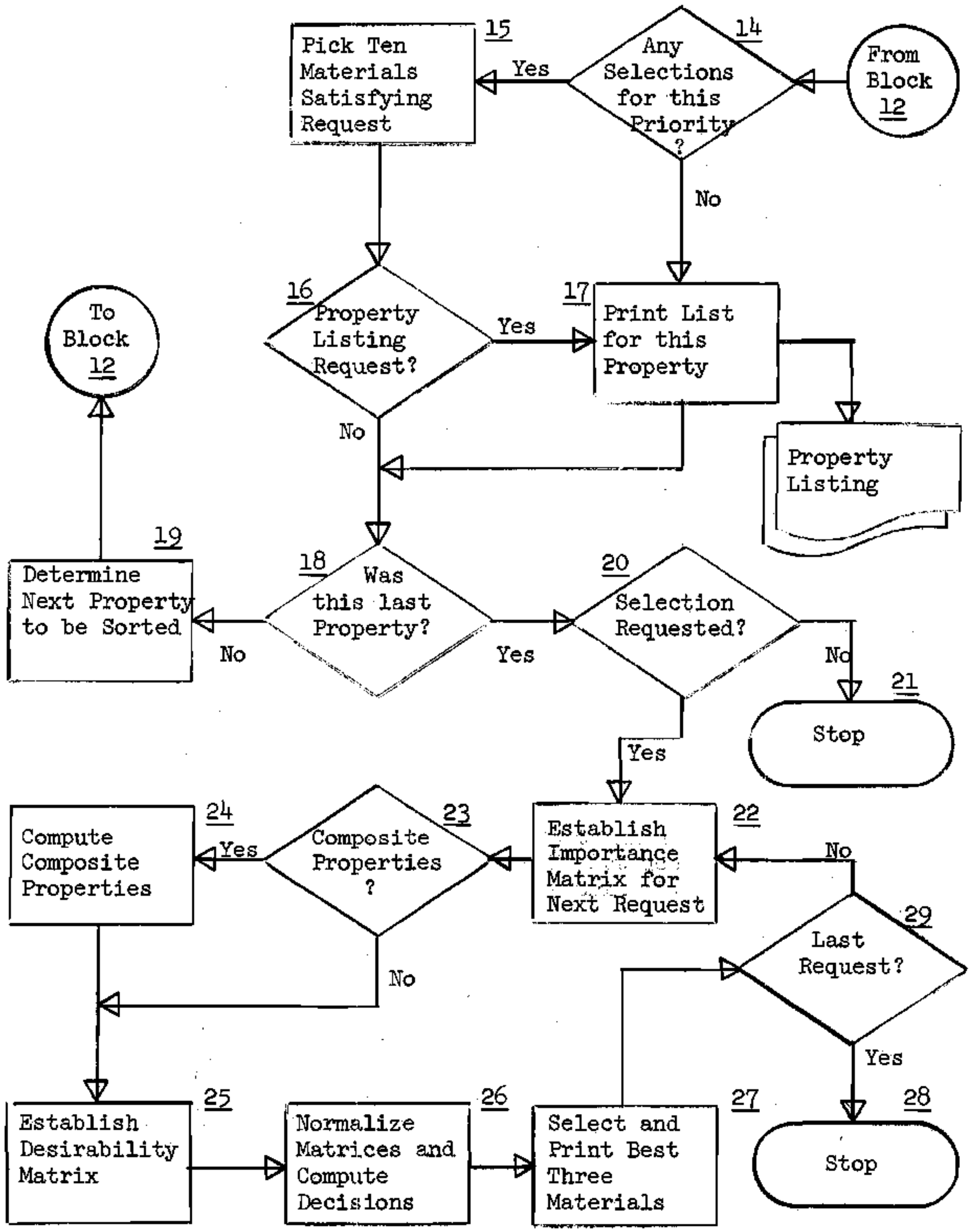

Figure 5. Program Flow Chart
(Continued from Figure 4)

request (14,17 or 14,15,16,17), it is also fulfilled. After all properties earmarked for sorting are processed in the same manner, the run is terminated (20,21) unless at least one selection request was encountered in the input data deck. In that case, for the first request, the Importance Matrix is built (22). Materials data (for each material that is in the list of possible materials) are checked to insure that they satisfy the limitations for properties other than the one on the basis of which the material was added to the list. If it passes these tests, then it is included in the desirability matrix. Composite properties are computed (if required), and rankings are also placed in the desirability matrix if necessary (23,24,25). Finally, both matrices (desirability and importance) are normalized and the decision index is evaluated for each material (26) as outlined in Chapter IV. On the basis of their computed desirabilities, the best three materials are printed out and the process is repeated for the next selection request (27,29,22). After the last request is processed, the execution is terminated (27,29,28).

Input Deck Setup

Illustrated in Figure 6, the input deck consists of:

1. MCP (Master Control Program) and COBOL compiler control cards
2. Program deck (in source or object language)
3. Data file control (introduction) card
4. Materials data catalog on cards, each material consisting of two cards, up to 161 materials (total capacity for this program).
5. Selection request cards, if any. One card is required for each request. Up to nine requests can be processed in each run.

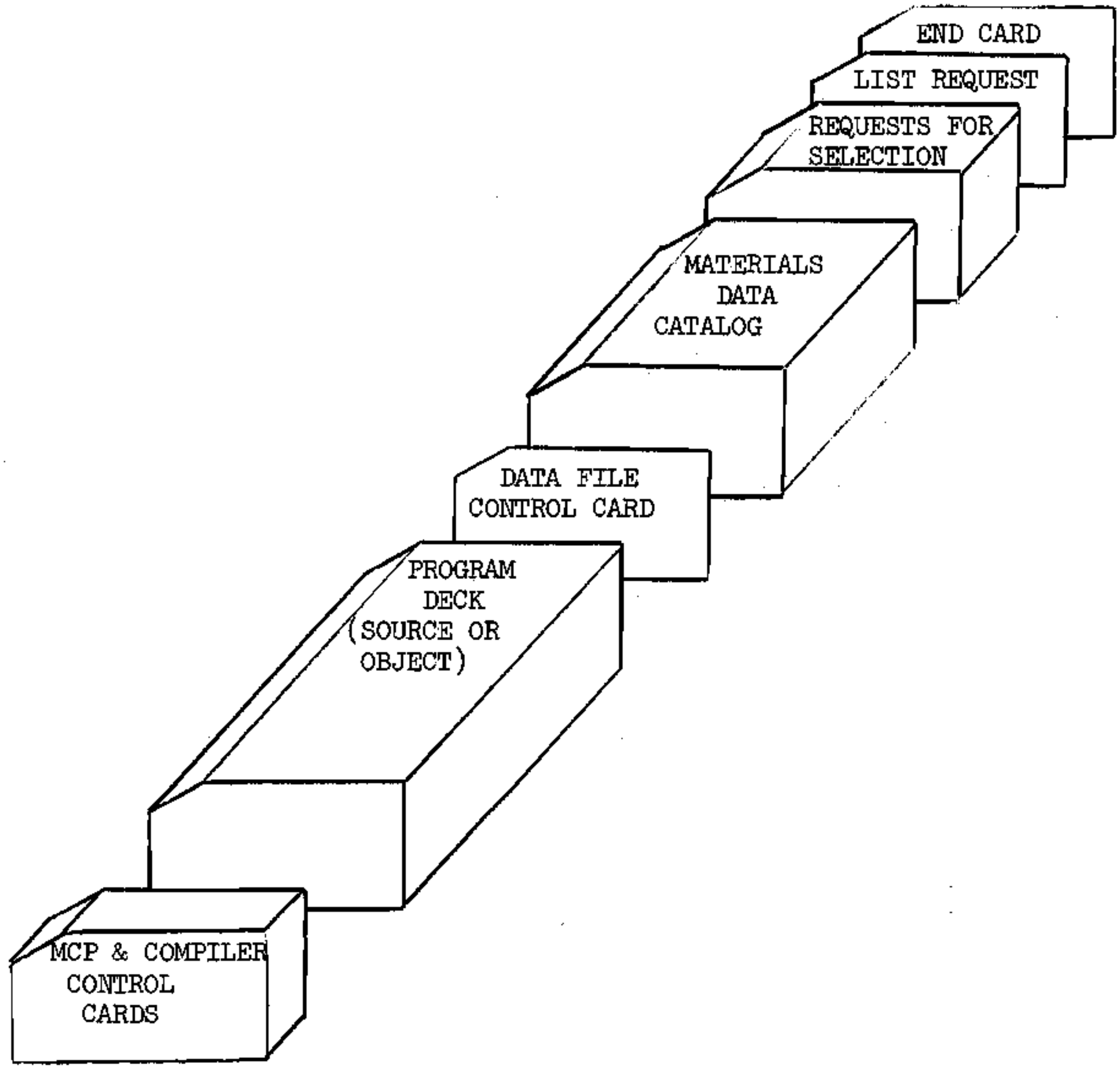

Figure 6. "CASEM" Input Deck Set Up for B-5500

6. Listing request card, if there is a listing request. Only one listing request card can be processed in each run.

7. End card (orange).

<u>Output Reports</u>

In addition to the error and program messages, three types of reports are generated if requested. These are:

1. Catalog listing tabulating all materials and all of their properties in a sequential order.

2. Property listings showing, in ascending or descending order, all materials for which data are available for a primary property.

3. Selection results, for up to nine requests, showing the results of the selection process in a tabular form with material numbers and relative desirabilities.

Samples of output reports are included in Appendix C.

<u>Warnings and Messages</u>

Error messages of a warning nature are printed during editing of input data. All error messages are preceded by: "XXXXXX WARNING FLAG-DATA SECTION." The error messages are:

1. "AAA CARD MISSING THEREFORE CARD NUMBER NNNNN IS EXCLUDED FROM THE CATALOG." where AAA is either "1ST" or "2ND" and NNNNN is the number of the card that is in error.

2. "THE FOLLOWING CARD IS UNIDENTIFIED, THEREFORE NOT PROCESSED:," followed by the image of the unidentified card.

3. "CATALOG DATA SUPPLIED EXCEEDS STORAGE CAPACITY, THUS ONLY 1ST 160 MATERIALS ARE COMPILED, CARD NUMBER NNNNN AND ALL MATERIALS DATA FOLLOWING THIS CARD ARE OMITTED."

4. "THE LISTING REQUEST CARD BELOW IS REJECTED, DO NOT COMPILE MORE THAN ONE:," followed by the image of the rejected card.

5. "THE SELECTION REQUEST CARD BELOW IS REJECTED, DO NOT COMPILE MORE THAN NINE:," followed by the image of the rejected card.

When an error condition is found during editing, the card that is in error is discarded and processing is continued.

The program prints three messages to supply information about completion of program phases. Each one preceded by "XXXXXXX PROGRAM MESSAGE:," these messages are:

1. "PROGRAM AND DATA HAVE BEEN COMPILED, CATALOG CONSISTS OF NNN ITEMS," where NNN is the number of materials in catalog.

2. "EXECUTION IS REQUESTED BUT CATALOG NOT SUPPLIED THEREFORE THIS COMPUTER RUN IS SUSPENDED: SUPPLY CATALOG WITH NEXT RUN."

3. "SUPPLIED CATALOG HAS BEEN READ IN AND FILED,--EXECUTION TERMINATED SINCE NEITHER LISTING NOR SELECTION IS REQUESTED."

User Procedures

Materials Catalog Maintenance

There are three activities associated with this phase of the system: additions, deletions, and changes to the catalog. The step-by-step procedures to be used for these activities are given below for various groups involved.

Engineering Department:

Step E1. Using Materials Data Form (Appendix E), indicate the type of request; add or change.

Step E2. If add, fill form according to instructions in Appendix A. Go to Step E5.

Step E3. If change, fill only the properties or fields to be changed. Columns 76-80 should contain the number of the card to be changed. Go to Step E5.

Step E4. If delete, indicate the numbers of materials to be deleted on Delete List (Appendix E).

Step E5. Date and sign the document and forward to Data Processing Department.

Data Processing Department:

Step D1. If change or delete, go to Step D5.

Step D2. Key punch the information from the document. All fields are numeric and right-justified except for Comments, Name, and Condition, which are alphabetical and left-justified.

Step D3. Key verify the punched cards (two per document).

Step D4. Place cards, in sequence, in the Materials Data Card File. Go to Step D10.

Step D5. If delete, locate the cards in the Sequential Materials Data Card File and remove. Go to Step D10.

Step D6. Locate card to be changed in Card File.

Step D7. Duplicate the unchanged portion of the old card, punching only the changed fields from the Materials Data Form.

Step D8. Key verify the newly punched fields.

Step D9. Place new cards in the Card File.

Step D10. Return deleted and changed cards and documents to Engineering Department to indicate the completion of the requested changes, additions, and/or deletions.

Listing and Selection Requests

Catalog and property listings can be obtained by filling in the Listing Request Form (Appendix F). For selection requests, use the Selection Request Form and follow the directions below:

Engineering Department:

Step S1. Determine, in numerical form if possible, all the important properties and qualities necessary. These would include design loads, price, corrosion, machinability, etc.

Step S2. Find the property numbers for each property or rating from Table 2.

Step S3. Decide the relative importance of each property or rating within its group on a scale of nine, where zero is the least important, and nine the most important.

Step S4. Decide the direction of optimization for each property (but not for ratings). If optimization is to be upward (i.e., the optimum value is the minimum acceptable), place 1 in the associated field (called "optimization" on the form), otherwise leave blank.

Step S5. Write the desired numerical values of each property in "Optimum Value" field. All ratings are on a scale of nine where nine indicates the best and zero the worst. Exceptions are Compressive Strength and Reduction in Area, where the rating is replaced by the actual numerical values, i.e., 26.7 percent reduction in area and 34 ksi compressive strength would be shown as ratings of 27 and 34, respectively.

Table 2. Materials Properties and Rankings

Property Number	Property	Unit
	PRIMARY PROPERTIES	
01	Yield strength	ksi; 1000 lb/sq in.
02	Tensile strength	ksi; 1000 lb/sq in.
03	Elongation	percent
04	Shear strength	ksi; 1000 lb/sq in.
05	Brinell hardness	Brinell hardness number; BHN
06	Modulus of elasticity	100,000 lb/sq in.; 100 ksi
07	Endurance limit	ksi; 1000 lb/sq in.
08	Machinability	basis: 100 for AISI B1112
09	Density	0.001 lb/cu in.
10	Coefficient of thermal expansion	0.00001/°F
11	Thermal conductivity	10 BTU/hr/sq ft/°F/ft
12	Comparative price	¢/lb
14	Melting point	°F
15	Electrical resistance	0.1 microohm-cm
	COMPOSITE PROPERTIES	
01	Specific stiffness	10^{8} inches
02	Stiffness price	10^{10} in.-lb/$
03	Specific strength	10^{6} inches
04	Strength price	10^{8} in-lb/$
	RATINGS	on a scale to 9
01	Corrosion resistance	industrial atmosphere
02		marine atmosphere
03		sea water
04		hydrochloric acid
05		sulphuric acid
06		ammonia
07	Creep characteristics	
08	Impact strength	
09	Wear resistance	
10	Availability	standard mill forms and sizes
11	Compressive strength	ksi; 1000 lb/sq in.
12	Reduction in area	percent

Step S6. When the form is completed, add date, sign, and forward to Data Processing Department.

Data Processing Department:

Step R1. Punch Selection Request Card from the Selection Request Form. Verify.

Step R2. Accumulate requests unless either the selection requests exceed eight in number of there is a listing request. Then go to Step R3.

Step R3. Set up the input deck with the CASEM program and Materials Data Card File as shown in Figure 6. Run the program.

Step R4. Forward all printed output to the Engineering Department for distribution. Forward Request Cards to originators of Request Forms. Return program and Materials Data Card File to Card Cabinet marked "Materials."

The procedures given above are intended as examples and obviously would have to be amended to fit the specific organization that is using the system.

Example

A U-cross-section roller guide, used in the landing gear assembly of a fighter plane is presently being cast from nodular iron (type 120-90-02). Recent vendor problems, however, caused the necessity of considering an alternate material and a possible switch from the present manufacturing method. Specifications and tests of the actual material show that it has a Brinell hardness of 250 and a tensile strength of 125 ksi, with a factor of safety of 2.50. If a substitute can be found, it preferably should be no heavier than the present weight, should have good wear characteristics, and although not extremely important, availability of a mill form close to the desired U-cross-section would be very convenient. Because of the amount of work that would be involved in redesigning the assembly, it is extremely undesirable to change the dimensional parameters from the present configuration.

Based on the statement of the problem given above, the selection criteria are:

1. Tensile strength of 125 ksi or more,

   Property number is 2 (from Table 2),

   Importance is judged to be 8 on a scale of nine,

   Optimization is upward (value 1).

2. Hardness of 250 Brinell or harder (after heat treatment, if any),

   Property number 5,

   Importance 7 (slightly less than strength, but still important)

   Optimization is upward (value 1).

3. Density 0.290 pounds per cubic inch or less,

   Property number is 9,

   As important as hardness; importance is judged 7,

   Optimization downward (blank).

4. Wear rating should be good, possibly 9,

   Importance judged 9, very important,

   Rating number is 9.

5. Availability is not very important, importance is judged to be 5,

Only with a high rating of availability might there be a possibility of finding a standard U-section, so it is assumed to be 9,

Rating number is 10.

These requirements are coded onto the Selection Request Form which is shown in Figure 7.

When this information is processed through the program, the following selections resulted:

First choice is Material #72 (wrought nitride steel, type EZ) with tensile strength of 126 ksi, Brinell hardness of 255, and a density of 0.283 lb/cu in. It is rated excellent for wear (9) but availability is average; therefore, likelihood of finding a standard U-section is not very good. Desirability of this selection was computed as 94 percent.

Second and third choices were also nitride steels (catalog numbers 66 and 69) and had desirabilities of 89 and 87 percent, respectively.

The outputs applying to this example are shown in Appendix C under request number 5.

CASEM

SELECTION REQUEST FORM

By: N.V.D.

Dept: Eng.

Date: 4/18/68

	Number	Importance	Optimization	Optimum Value	Card Columns
Card Code	4				01
PRIMARY PROPERTIES	02	8	1	125	02-09
	05	7	1	250	10-17
	09	7		290	18-25
					26-33
					34-41
RATINGS	09	9		9	42-46
	10	5		9	47-51
					52-56
					57-61
COMPOSITE PROPERTIES					62-67
					68-73
					74-79
Request	5				80

Figure 7. Selection Request Form for the Example

CHAPTER VI

RECOMMENDATIONS AND SUGGESTIONS

The principal objective of this work was to develop a computer-based pilot system for cataloging engineering materials data and making selections from that data base to fulfill specific property requirements.

As implied by the word "pilot," further work in this field is not only desirable and justified but also necessary.

The following suggestions should provide a basis for further development of this system:

1. Dissemination of timely and uniformly accurate data for new materials is most important to the designer, with or without this system. Therefore, it would be very desirable to prepare a detailed proposal for a "master plan" for standardizing such activities.

2. A method of comparison should be developed for properties that are compared only through ratings in this system.

3. Efforts should be undertaken to expand the Materials Catalog from the existing pool of 160 materials. The quality of selections will improve in direct proportion to the size of the catalog.

4. Processing time and core memory requirements should be reduced by utilizing the following recommendations for the CASEM computer program:

   a. Data should be transferred to and be kept on disk or tape files rather than cards, thus improving the core usage.

b. The program should be broken into three smaller programs independently executed but using the same file. These would be:

(1) Catalog Maintenance Program

(2) Catalog Listing Program

(3) Selection Program.

c. Possibilities should be investigated for the feasibility of use through remote terminals in a conversational mode. In this instance, the program would interrogate the designer on a real time basis, to obtain the criteria necessary for selection.

5. The possibility of establishing conversion tables for use (only to provide a basis for comparison) in comparing properties tested by different methods for different materials should be investigated.

6. A method should be devised to make the initial decision as to what class of materials is to be considered for selection.

7. Fabrication methods that can be used with each material should be made a part of the data for each material so evaluations can be made on the basis of fabrication equipment available at the manufacturing location.

The system presented here can evolve into a major tool for the design engineer and greatly reduce the efforts required of him in this field as well as improve his selections. But most importantly, activities of this nature provide a thrust toward a better understanding of the logical processes involved. Thus it is hoped that even the simple activity of preparing the data for this system will help the designer to grasp the explicit meanings of the assumptions he makes and judgments he exercises to make a material selection.

APPENDIX A

STATISTICAL DECISIONS

The following is a brief review of those aspects of the Statistical Decision Theory necessary for the development of a material selection technique.

Notation

Symbol X represents the vector $X_1,\ldots,X_m$, denoting the random variables on which the decision is to be based. Symbol Y represents the vector $Y_1,\ldots,Y_m$, denoting the random variables that will be observed after the decision is made. Symbol D is an index for possible decisions. Symbol s denotes a decision rule defined by non-negative numbers s(x;D), where s(x;D) is the probability assigned by the decision rule s to choosing the decision D when X = x. If L is the number of values D can take, then by definition:

$$\sum_{D=1}^{L} s(x;D) = 1 \quad \text{for each } x.$$

Symbol θ is an index for the possible joint distributions of X and Y. The loss incurred when X = x, Y = y and decision chosen is D is W(y;D;x) or W(y;D), when it does not depend on X explicitly. By definition, the expected value of a loss is

$$r(\theta;s) = \sum_{x} \sum_{D=1}^{L} R(\theta;x;D)\; s(x;D)$$

when the decision rule s is used and where $R(\theta;x;D)$ is the loss function.

Evaluation

In general, a decision rule is said to be "good" when $r(\theta;s)$ is small for all θ. If s_1 and s_2 are two decision rules, s_1 is said to be better than s_2 if:

$$r(\theta;s_1) \leqq r(\theta;s_2) \quad \text{for all } \theta \qquad \text{and,}$$

$$r(\theta;s_1) < r(\theta;s_2) \quad \text{for at least one value of } \theta.$$

A decision rule t is called "inadmissible" if there is a decision rule which is better than t. Any decision rule that is not inadmissible is "admissible."

Bayesian Decision Rules

If $b(1),\ldots\ldots,b(h)$ are non-negative numbers adding to unity, then a decision rule s is called "Bayesian relative to $b(1),\ldots,b(h)$," if:

$$\sum_{\theta=1}^{h} b(\theta)\ r(\theta;a) \leqq \sum_{\theta=1}^{h} b(\theta)\ r(\theta;t)$$

for each and every decision rule t. Therefore any admissible decision rule is a Bayesian Decision Rule. However, some inadmissible decision rules are also Bayesian (36).

To construct a Bayesian decision rule relative to $b(1),\ldots,b(h)$, s should be chosen to minimize the expression:

$$\sum_{x} \sum_{D=1}^{L} s(x;D)\ K(D;x)$$

where $K(D;x)$ is the loss function associated with $b(1),\ldots,b(h)$ for all θ and all Y. Obviously $s(D;x)$ has to be set equal to zero for each pair of x and D, unless $K(D;x) = \min\{K(1;x),\ldots\ldots,K(L;x)\}$. If for some x, $K(D;x)$ is minimized for more than one value of D, then there is more than one Bayesian decision rule relative to $b(1),\ldots,b(h)$.

Desirabilities and Probabilities

Construction of Bayesian Decision Rules when there is a finite number of distributions and a finite number of decisions, has been studied in detail by Jeffrey (35). In resulting methods, a set of more descriptive labels evolved to describe matrices represented by $r(\theta,s)$ and vectors represented by $b(\theta)$. $r(\theta,s)$ is referred to as the "Desirability" matrix and $b(\theta)$ is called the "Probability" vector. The product matrix represented by the element $b(\theta)r(\theta,s)$, the sums of which must be minimized to give a Bayesian decision rule, is termed the "Consequence," "Expected Desirability," or the "Decision" matrix.

APPENDIX B

NOTES ON THE COMPILATION OF MATERIALS DATA

New materials are added to the Materials Data Card File (catalog) by the use of the Materials Data Form shown in Figure 8 in Appendix E. The same form is used for revising the data already in the catalog.

All numerical fields on the form are filled in right-justified, and alphabetical fields are left-justified. It is of utmost importance that all numerical data that do not conform to the units as shown on the form be converted by the use of conversion tables and conversion factors commonly available in professional handbooks.

If the form is being used only to change existing data, the appropriate box should be checked. In this case, only the field that is to be changed need be filled. For identification purposes, Class, Subclass, Name, Condition, and Card Number must also be shown.

For the addition of new data to the catalog, the following points should be kept in mind:

1. Data are punched on two cards per material. Card codes 1 and 2 (first column of each card) indicate first and second cards, respectively.

2. Class and Subclass numbers are assigned from Tables 3, 4, and 5. Their purpose is to facilitate preselection comparisons on the basis of dominant properties of each group of materials in future work.

Table 3. Materials Classification

Class	Materials
1	Ferrous metals
2	Non-ferrous metals
3	Plastics
4	Rubber, ceramics, glass, carbon

Table 4. Subclasses for Ferrous Metals (Class 1)

Subclass	Materials
01	Grey cast iron
02	Nodular or ductile cast iron
03	Malleable (cast) irons
04	White and alloy cast irons
05	Ingot and wrought irons
06	Carbon steels--hardening grade
07	Carbon steels--carburizing grade
08	Nitriding steels--wrought
09	H-steels--wrought
10	Alloy steels--wrought
11	High strength steels--wrought
12	Ultra-high strength steels (wrought)
13	Free-cutting steels--wrought
14	High temperature steels--wrought
15	Austenitic stainless steels--wrought
16	Ferritic stainless steels--wrought
17	Martensitic stainless steels--wrought
18	Age hardenable stainless steels
19	Iron-based super alloys--wrought, cast
20	Iron-based chromium-nickel super alloys (cast)
21	Carbon steels--cast
22	Alloy steels--cast
23	Cast stainless steels
24	Heat resistant alloys--cast
25	Tool steels (wrought)
26	Alloy steels--quenched and tempered
27	Ferrous metal powders
28-99	Unused

Table 5. Subclasses for Non-ferrous Metals (Class 2)

Subclass	Material
01	Wrought aluminum
02	Cast aluminum
03	Cobalt and cobalt-based super alloys
04	Tantalum, tungsten, molybdenum (wrought)
05	Wrought columbium
06	Wrought copper
07	Copper base cast alloys
08	Lead--cast or wrought
09	Wrought magnesium alloys
10	Cast magnesium alloys
11	Non-ferrous metal powders
12	Rare earth metals
13	Nickel and alloys--wrought
14	Nickel and alloys--cast
15	Low-expansion nickel alloys (wrought)
16	Nickel base super alloys
17	Precious metals--wrought
18	Tin--wrought, cast
19	Tin-lead-antimony alloys--cast
20	Titanium--wrought
21	Wrought zinc alloys
22	Cast zinc alloys
23	Hafnium, throium, uranium, vanadium, and beryllium--wrought
24	Wrought zirconium and its alloys
25-99	Unused

3. All numerical values compiled in this study represent average values. They vary depending on the manufacturer. When the system is installed, if available, values representing materials in use at that specific location should be compiled.

4. Property values used here are reported to be determined by standard tests at room temperature and under normal conditions; unless otherwise indicated. Consistency and uniformity throughout the catalog are at least as important as the individual testing methods employed to determine the numerical values.

5. Where manufacturing methods cause appreciable difference in properties, the same material manufactured in several ways has been treated as several different materials, method of manufacture being indicated in the "Condition" field (i.e., hot rolled, cold rolled, etc.) or implied by the subclass selection (e.g., Class 2, subclass 13: "Nickel and alloys--wrought," versus subclass 14: "Nickel and alloys--cast").

6. Yield strength values are at 0.2 percent offset.

7. Shear strength values for wrought steels are taken to be 60 percent of the yield strength if explicit numerical values were not available.

8. Rockwell "C" and shore hardness values were converted to Brinell to make comparisons possible.

9. Values shown for modulus of elasticity are in tension.

10. Values given for fatigue strength are endurance limits in ksi for 10^6 cycles.

11. Machinability indexes are based on AISI B1112 : 100.

12. Columns 52-75 on both cards are reserved for comments and will not be processed by the system.

13. Card numbers are to be unique, and assigned sequentially so they can be used to quickly identify cards to be changed or deleted during maintenance.

14. Prices are given only as comparative values and do not reflect pricing structures and manufacturing costs as they may apply to specific locations.

15. Material name should be as descriptive as possible within the given 25-character limit. Note that, because of report format space restrictions, middle three characters (the three positions of the middle line on the form) will not be printed in listings.

16. "Condition" should describe the material when the reported properties were measured. Some examples are: cast, wrought, annealed, pearlitic, cold worked, investment cast, etc.

17. All ratings are based on a maximum of nine with the exception of compressive strength and reduction in area, which are explained below in items 19 and 20. A rating of nine indicates that the material so rated is very suitable for such applications.

18. Corrosion ratings are developed from published information and should be replaced if possible by judgments based on past experience at the specific location where the system is being used.

19. Compressive strength ratings are actual values in ksi and, if 100 or higher, 99 should be substituted.

20. Reduction in area ratings are rounded percentage values as obtained from tests.

21. A high creep rating indicates that rated material shows a relatively low rate of creep up to 1000°F.

22. Impact ratings should be based on impact strength as determined by Notched-Izod test.

23. A high wear rating indicates good wear characteristics.

24. Availability ratings refer to variety and intricacy of commercially available shapes and cross sections such as sheets, bar-stock, hollow sections, etc.

Sources of Materials Data

Sources of materials and data used in this study are listed below:

--Metals Reference Issue, Machine Design, September 1965.

--J. M. Alexander, Manufacturing Properties of Materials, Van Nostrand Co., New York, 1963.

--R. L. Peters, Materials Data Nomographs, Reinhold Publishing Corp., New York, 1965.

--SAE Handbook, Society of Automotive Engineers, New York, 1965.

--C. A. Keyser, Materials of Engineering, Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1956.

Items 4, 5, 6, 12, 14, 15, and 19 listed under "Literature Cited" are also used but not listed here to avoid duplication.

APPENDIX C

SAMPLES OF COMPUTER OUTPUT FROM CASEM

Samples of computer printouts follow this page in the following order:

1. General Catalog Listing Header Page
2. Sample page from the Catalog Listing
3. Property Listing for Tensile Strength
4. Property Listing for Brinell Hardness
5. Property Listing for Density
6. An alphabetical listing of materials in the catalog
7. A typical output page showing selection results for six selections (requests 0 through 5).

All materials and properties used for the example in Chapter V are marked with asterisks for ease of reference.

GENERAL TABLE

A LISTING OF ALL MATERIALS AND PROPERTIES COMPILED IN THE CATALOG

-IN THE ORDER OF COMPILATION-

NOTES : 1-CLASSES 1 AND 2 INDICATE FERROUS AND NON-FERROUS METALS RESPECTIVELY; FOR A DISCUSSION OF SUBCLASSES REFER TO THE TEXT.

2-VALUES LISTED FOR FATIGUE ARE ENDURANCE LIMITS GIVEN IN KSI.

3-VALUES FOR MACHINABILITY ARE BASED ON AISI B1112 = 100.

4-ALL RATINGS ARE RELATIVE VALUES; 1 AND 4 INDICATE LEAST AND MOST DESIRABLE APPLICATIONS, RESPECTIVELY.

5-PRICES ARE GIVEN ONLY AS A COMPARATIVE MEASURE OF THE VALUE.

6-FOLLOWING UNITS ARE NOT SHOWN IN THE TABLE FOR THE SAKE OF SIMPLICITY :

MODULUS OF ELASTICITY (100000 PSI)
ELECTRICAL RESISTANCE (.1 MICROOHM-CM)
THERMAL CONDUCTIVITY (10 BTU/HR/SQ.FT/F/FT)
COEF. OF THERMAL EXPANSION (1/DEG.F)

CATALOG NUMBER	65	* 66	67	68	* 69	70	71	* 72
CLASS	1	1	1	1	1	1	1	1
SUBCLASS	7	8	8	8	8	8	8	8
NAME / CONDITION	CARBON STL. AISI C1118 CARBURIZING	NITRIDE STL TYPE 135 WROUGHT	NITRIDE STL TYPE 135 WROUGHT	NITRIDE STL TYPE 135MD WROUGHT	NITRIDE STL TYPE 135MD WROUGHT	NITRIDE STL TYPE N WROUGHT	NITRIDE STL TYPE N* WROUGHT	NITRIDE STL TYPE EZ WROUGHT
STRENGTH - YIELD (KSI)	77	120	103	141	125	114	180	90
STRENGTH - TENSILE (KSI)	113	130	121	159	145	132	190	125
STRENGTH - SHEAR (KSI)								
STRENGTH - FATIGUE	57			90	90			
STRENGTH - COMPRESSIVE (KSI)								
ELONGATION (%)	17	20	23	18	20	22	15	17
REDUCTION IN AREA (%)	45							
BRINNEL HARDNESS	670	280	230	320	285	277	415	255
MACHINABILITY								
RATINGS - CORROSION - INDUSTRIAL ATM.								
RATINGS - CORROSION - MARINE ATM.								
RATINGS - CORROSION - SEA WATER								
RATINGS - CORROSION - H CL								
RATINGS - CORROSION - H2 SO4								
RATINGS - CORROSION - N H3								
RATINGS - CREEP								
RATINGS - IMPACT								
RATINGS - WEAR		9	9	9	9		9	9
RATINGS - AVAILABILITY	9	5	5	5	5		5	5
PRICE ($ / LB.)								
MODULUS OF ELASTICITY	295	295	295	295	295	285	285	285
DENSITY (LB./CU.IN.)	283	283	283	283	283	283	283	283
MELTING POINT (DEG.F)	2763							
ELECTRICAL RESISTANCE	183	280	280	280	280	280	280	280
THERMAL CONDUCTIVITY	270	30	30	30	30	30	30	30
COEF.OF THERMAL EXPAN.	64	65	65	65	65	65	65	65

LISTING OF THE MATERIALS IN THE CATALOG---PROPERTY LISTED IN THE TABLE BELOW IS:

TENSILE STRENGTH

UNITS : 1000 PSI

IN THE TABLE BELOW : COLUMN 1 LISTS THE CATALOG NO
COLUMN 2 LISTS THE CLASS
COLUMN 3 LISTS THE SUBCLASS
COLUMN 6 LISTS THE PROPERTY

FOR OTHER PROPERTIES OF ANY MATERIAL LISTED BELOW
REFER TO THE GENERAL TABLE

	1	2	3	MATERIAL NAME	CONDITION	6	1	2	3	MATERIAL NAME	CONDITION	6
	11	1	3	MALLEABLE C.I.GR35018	FERRITIC	530	130	1	21	CARBON STL.CLASS 60000	ANNEALED	63
	86	1	10	ALLOY STEEL AISI 4063	WROUGHT	345	14	1	1	GRAY IRON CLASS 60	CAST	63
	85	1	10	ALLOY STEEL AISI 5160	WROUGHT	322	9	1	2	CAST IRON AUSTENITIC	CAST	63
	82	1	10	ALLOY STEEL AISI 6150	WROUGHT	315	141	2	1	ALUMINUM-WR ALLOY 5056	HARDND H38	60
	81	1	10	ALLOY STEEL AISI 5150	WROUGHT	312	100	2	6	TANTALUM - WROUGHT	@ ROOM TEMP	60
	84	1	10	ALLOY STEEL AISI 9255	WROUGHT	305	90	2	8	ARCH.BRONZE CDA # 385	ANNEALED	60
	80	1	10	ALLOY STEEL AISI 4150	WROUGHT	301	53	1	6	CARBON STL. AISI C1040	HARD.GRADE	60
	79	1	10	ALLOY STEEL AISI 8740	WROUGHT	290	19	1	4	MOLYBDENUM ALLOY IRON	CAST	60
	76	1	10	ALLOY STEEL AISI 4140	WROUGHT	290	109	2	8	NAVAL BRASS-WR CDA#467	ANNEALED	57
	77	1	10	ALLOY STEEL AISI 4340	WROUGHT	284	108	2	8	MUNTZ METAL-WR CDA#280	ANNEALED	54
	83	1	10	ALLOY STEEL AISI 8650	WROUGHT	282	87	2	8	MUNTZ METALFREE-CUTTIN	ANNEALED	54
	75	1	10	ALLOY STEEL AISI 3110	WROUGHT	280	13	1	1	GRAY IRON CLASS 50	CAST	54
	78	1	10	ALLOY STEEL AISI 5140	WROUGHT	278	111	2	8	COPPERALLOY-WR CDA#757	ANNEALED	52
	74	1	10	ALLOY STEEL AISI 4130	WROUGHT	234	89	2	8	BRASS-FORGE CDA # 377	ANNEALED	52
	101	2	6	TUNGSTEN - WROUGHT	@ ROOM TEMP	220	16	1	4	WHITE IRON	CAST	50
	73	1	8	NITRIDE STLTYPE:5NI2AL	WROUGHT	206	10	1	3	MALLEABLE C.I.GR32510	FERRITIC	50
	71	1	8	NITRIDE STLTYPE : N	WROUGHT	190	91	2	8	BRASS--FREE CUTTING	ANNEALED	49
	124	1	15	STN.STL.-WR AISI 301	ANNEALED	185	41	2	28	ZIRCONIUM--REACTOR GR.	@ ROOM TEMP	49
	30	2	3	COBALT AL-LOY : NIVCO	ROOM TEMP.	165	37	2	27	VANADIUM	COLD WORKED	49
	68	1	8	NITRIDE STLTYPE:135MO	WROUGHT	159	35	2	27	THORIUM	COLD WORKED	49
	121	2	24	TITANIUM ALLOY 7AL-4MO	WR.@ROOM T.	145	27	1	5	WROUGHTIRONLONG.PROP.S	HOT ROLLED	48
*	69	1	8	NITRIDE STLTYPE:135MO*	WROUGHT	145	154	2	1	ALUMINUM-WR ALLOY 5086	HARDND H34	47
	98	2	4	COBALT SUPERALLOY S816	WROUGHT	140	96	2	2	ALUMINUM ALLOY A380	DIE CAST	47
*	66	1	8	NITRIDE STL TYPE:135	WROUGHT	138	146	2	1	ALUMINUM-WR ALLOY 5083	HARDND H113	46
	7	1	2	CAST IRON 120-90-02	CAST	135	112	2	9	TIN BRONZE ASTI GR.2A	CAST	45
	70	1	8	NITRIDE STLTYPE : N	WROUGHT	132	45	2	28	ZIRCONIUM--TYPE : AIR	@ 600 F.	45
	131	1	22	ALLOY STEELCLASS120000	CAST	128	22	1	4	HIGH-NICKELALLOY IRON	CAST	45
*	72	1	8	NITRIDE STLTYPE : EZ	WROUGHT	126	21	1	4	HIGH-SILICAALLOY IRON	CAST	45
	103	2	6	T2W ALLOY -WROUGHT	@ ROOM TEMP	125	110	2	8	CUPRONICKEL-WR CDA#706	ANNEALED	44
	67	1	8	NITRIDE STL TYPE:135*	WROUGHT	121	25	1	5	INGOT IRON	HOT ROLLED	44
	60	1	6	CARBON STL. AISI C1144	HARD.GRADE	117	12	1	1	GRAY IRON CLASS 40	CAST	44
	65	1	7	CARBON STL. AISI C1118	CARBURIZING	113	116	2	11	MG ALLOY ASTM AZ61A-F	FORGED	43
	106	2	7	B-66 ALLOY WROUGHT	@ ROOM TEMP	112	145	2	1	ALUMINUM-WR ALLOY 5083	ANNEALED	42
	32	2	27	HAFNIUM	COLD WORKED	112	140	2	1	ALUMINUM-WR ALLOY 5056	ANNEALED	42
	120	2	16	MONEL 505	CAST	110	139	2	1	ALUMINUM-WR ALLOY 5052	HARDND H38	42
	6	1	2	CAST IRON 100-75-04	CAST	110	24	1	5	INGOT IRON	ANNEALED	42
	104	2	6	AVC ALLOY -WROUGHT	@ ROOM TEMP	105	144	2	1	ALUMINUM-WR ALLOY 3004	HARDND H38	41
	59	1	6	CARBON STL. AISI C1141	HARD.GRADE	103	105	2	7	COLUMBIUM -WROUGHT	@ ROOM TEMP	40
	99	2	5	COBALT SUPERALLOY HS21	INVEST.CAST	101	153	2	1	ALUMINUM-WR ALLOY 5086	ANNEALED	38
	51	1	3	MALLEABLE C.I.80002	PEARLITIC	100	138	2	1	ALUMINUM-WR ALLOY 5052	HARDND H34	38
	4	1	2	CAST IRON 80-60-3	CAST	100	107	2	8	BRONZE - WR CDA #220	ANNEALED	37
	64	1	7	CARBON STL. AISI C1117	CARBURIZING	97	158	2	1	ALUMINUM-WR ALLOY 5154	ANNEALED	35
	58	1	6	CARBON STL. AISI C1137	HARD.GRADE	96	143	2	1	ALUMINUM-WR ALLOY 3004	HARDND H34	35
	129	1	17	STN.STL.-WR AISI 420	ANNEALED	95	95	2	2	ALUMINUM ALLOY 40-E	CAST + AGED	35

102	2	6	MOLYBDENUM WROUGHT	@ ROOM TEMP	95	113	2	9	YELLOWBRASS ABTI GR.6B	CAST	34
126	1	15	STN.STL.-WR AISI 321	ANNEALED	90	36	2	27	VANADIUM	ANNEALED	34
118	2	15	DURANICKEL-WR TYPE 301	ANNEALED	90	34	2	27	THORIUM	ANNEALED	34
23	1	4	NI-ALUMINUMALLOY IRON	CAST	90	28	2	3	COBALT	ROOM TEMP.	34
18	1	4	HIGH CHROMEALLOY IRON	CAST	90	3	1	1	GRAY IRON CLASS 30	CAST	33
57	1	6	CARBON STL. AISI C1095	HARD.GRADE	89	157	2	1	ALUMINUM-WR ALLOY 5050	HARDND H34	32
127	1	16	STN.STL.-WR AISI 405	COLD WORKED	85	44	2	28	ZIRCALOY-2	@ 600 F.	30
125	1	15	STN.STL.-WR AISI 316	ANNEALED	84	40	2	28	ZIRCONIUM--COMMERCIAL	@ 600 F.	30
63	1	7	CARBON STL. AISI C1022	CARBURIZING	82	152	2	1	ALUMINUM-WR ALLOY 5005	HARDND H18	29
88	2	8	MUNTZ METALFREE-CUTTIN	HARD	80	136	2	1	ALUMINUM-WR ALLOY 3003	HARDND H18	29
50	1	3	MALLEABLE C.I.60003	PEARLITIC	80	117	2	12	MG ALLOY ASTM AZ63A	CAST	29
49	1	3	MALLEABLE C.I.53004	PEARLITIC	80	156	2	1	ALUMINUM-WR ALLOY 5050	HARDND H34	28
8	1	2	CAST IRON HEAT RESIST	CAST	80	137	2	1	ALUMINUM-WR ALLOY 5052	ANNEALED	28
114	2	9	ALUM.BRONZE ABTI GR.9A	SAND CAST	79	93	2	2	ALUMINUM ALLOY A108	CAST	28
31	2	27	HAFNIUM	ANNEALED	77	2	1	1	GRAY IRON CLASS 25	CAST	28
62	1	7	CARBON STL. AISI C1020	CARBURIZING	75	133	2	1	ALUMINUM-WR TYPE EC	HARDND H19	27
55	1	6	CARBON STL. AISI C1060	HARD.GRADE	75	97	2	2	ALUMINUM ALLOY TYPE319	SAND CAST	27
52	1	6	CARBON STL. AISI C1030	HARD.GRADE	75	142	2	1	ALUMINUM-WR ALLOY 3004	ANNEALED	26
48	1	3	MALLEABLE C.I.50007	PEARLITIC	75	151	2	1	ALUMINUM-WR ALLOY 5005	HARDND H14	23
38	2	27	BERYLLIUM	ANNEALED	75	1	1	1	GRAY IRON CLASS 20	CAST	23
33	2	27	URANIUM (DEPLETED)	ANNEALED	75	135	2	1	ALUMINUM-WR ALLOY 3003	HARDND H14	22
17	1	4	NICKEL-HARDALLOY IRON	CAST	75	155	2	1	ALUMINUM-WR ALLOY 5050	ANNEALED	21
81	1	7	CARBON STL. AISI C1015	CARBURIZING	73	122	2	25	ZINC-ROLLED COMMERCIAL	HOT ROLLED	21
26	1	5	INGOT IRON	COLD DRAWN	73	149	2	1	ALUMINUM-WR TYPE 1060	HARDND H18	19
128	1	17	STN.STL.-WR AISI 410	ANNEALED	70	94	2	2	ALUMINUM ALLOY TYPE 43	CAST	19
123	1	13	STEEL - WR AISI B1112	FREE-CUTTIN	70	42	2	28	ZIRCONIUM--REACTOR GR.	@ 600 F.	19
119	2	16	INCONEL 610	CAST	70	160	2	1	ALUMINUM-WR TYPE 1100	HARDND H14	18
47	1	3	MALLEABLE C.I.48004	PEARLITIC	70	150	2	1	ALUMINUM-WR ALLOY 5005	ANNEALED	18
5	1	2	CAST IRON 60-45-10	CAST	70	20	1	4	HIGH-SILICALLOY IRON	CAST	18
92	2	8	BRASS--FREE CUTTING	HARD	68	138	2	1	ALUMINUM-WR ALLOY 3003	ANNEALED	16
46	1	3	MALLEABLE C.I.45007	PEARLITIC	68	148	2	1	ALUMINUM-WR TYPE 1060	HARDND H14	14
43	2	28	ZIRCALOY-2	@ ROOM TEMP	68	159	2	1	ALUMINUM-WR TYPE 1100	ANNEALED	13
58	1	6	CARBON STL. AISI C1050	HARD.GRADE	65	132	2	1	ALUMINUM-WR TYPE EC	ANNEALED	12
15	1	3	MALLEABLE C.I.GR45010	PEARLITIC	65	147	2	1	ALUMINUM-WR TYPE 1060	ANNEALED	10
39	2	28	ZIRCONIUM--COMMERCIAL	@ ROOM TEMP	64	115	2	10	LEAD(1%SB)-WROUGHT	ROLLED	3

LISTING OF THE MATERIALS IN THE CATALOG---PROPERTY LISTED IN THE TABLE BELOW IS:

BRINNEL HARDNESS

IN THE TABLE BELOW : COLUMN 1 LISTS THE CATALOG NO
COLUMN 2 LISTS THE CLASS
COLUMN 3 LISTS THE SUBCLASS
COLUMN 6 LISTS THE PROPERTY

FOR OTHER PROPERTIES OF ANY MATERIAL LISTED BELOW
REFER TO THE GENERAL TABLE

	1	2	3	MATERIAL NAME	CONDITION	6	1	2	3	MATERIAL NAME	CONDITION	6
	64	1	7	CARBON STL. AISI C1117	CARBURIZING	740	39	2	28	ZIRCONIUM--COMMERCIAL	@ ROOM TEMP	179
	63	1	7	CARBON STL. AISI C1022	CARBURIZING	684	52	1	6	CARBON STL. AISI C1030	HARD,GRADE	178
	62	1	7	CARBON STL. AISI C1020	CARBURIZING	684	58	1	6	CARBON STL. AISI C1137	HARD,GRADE	174
	61	1	7	CARBON STL. AISI C1015	CARBURIZING	684	9	1	2	CAST IRON AUSTENITIC	CAST	170
	65	1	7	CARBON STL. AISI C1118	CARBURIZING	670	124	1	15	STN.STL.-WR AISI 301	ANNEALED	165
	85	1	10	ALLOY STEEL AISI 5160	WROUGHT	627	5	1	2	CAST IRON 60-45-15	CAST	155
	86	1	10	ALLOY STEEL AISI 4063	WROUGHT	605	2	1	1	GRAY IRON CLASS 25	CAST	165
	84	1	10	ALLOY STEEL AISI 9255	WROUGHT	601	88	2	8	MUNTZ METALFREE-CUTTIN	HARD	162
	82	1	10	ALLOY STEEL AISI 6150	WROUGHT	601	126	1	15	STN.STL.-WR AISI 321	ANNEALED	160
	81	1	10	ALLOY STEEL AISI 5150	WROUGHT	601	1	1	1	GRAY IRON CLASS 20	CAST	160
	80	1	10	ALLOY STEEL AISI 4150	WROUGHT	578	45	2	28	ZIRCONIUM--TYPE I ATR	@ 600 F.	159
	79	1	10	ALLOY STEEL AISI 8740	WROUGHT	578	128	1	17	STN.STL.-WR AISI 410	ANNEALED	155
	76	1	10	ALLOY STEEL AISI 4140	WROUGHT	578	125	1	15	STN.STL.-WR AISI 316	ANNEALED	149
	17	1	4	NICKEL-HARDALLOY IRON	CAST	565	123	1	13	STEEL - WR AISI B1112	FREE-CUTTIN	149
	83	1	10	ALLOY STEEL AISI 8650	WROUGHT	555	36	2	27	VANADIUM	ANNEALED	149
	77	1	10	ALLOY STEEL AISI 4340	WROUGHT	555	92	2	8	BRASS--FREE CUTTING	HARD	148
	75	1	10	ALLOY STEEL AISI 3110	WROUGHT	555	91	2	8	BRASS--FREE CUTTING	ANNEALED	148
	78	1	10	ALLOY STEEL AISI 5140	WROUGHT	534	26	1	5	INGOT IRON	COLD DRAWN	142
	19	1	4	MOLYBDENUM ALLOY IRON	CAST	525	10	1	3	MALLEABLE C.I.GR32510	FERRITIC	133
	20	1	4	HIGH-SILICAALLOY IRON	CAST	475	130	1	21	CARBON STL.CLASS 60000	ANNEALED	131
	18	1	4	HIGH CHROMEALLOY IRON	CAST	475	113	2	9	YELLOWBRASS BBII GR.6B	CAST	130
	74	1	10	ALLOY STEEL AISI 4130	WROUGHT	461	42	2	28	ZIRCONIUM--REACTOR GR.	@ 600 F.	129
	16	1	4	WHITE IRON	CAST	440	41	2	28	ZIRCONIUM--REACTOR GR.	@ ROOM TEMP	129
	71	1	8	NITRIDE STLTYPE : N	WROUGHT	415	118	2	9	ALUM.BRONZE BBII GR.9A	SAND CAST	120
	11	1	3	MALLEABLE C.I.GR35018	FERRITIC	330	90	2	8	ARCH.BRONZE CKA # 385	ANNEALED	110
	68	1	8	NITRIDE STLTYPE:135MD	WROUGHT	320	154	2	1	ALUMINUM-WR ALLOY 5086	HARDND H34	105
*	69	1	8	NITRIDE STLTYPE:135MD*	WROUGHT	285	146	2	1	ALUMINUM-WR ALLOY 5083	HARDND H113	105
	7	1	2	CAST IRON 120-90-02	CAST	285	133	2	1	ALUMINUM-WR TYPE EC	HARDND H19	105
*	66	1	8	NITRIDE STL TYPE:135	WROUGHT	280	27	1	5	WROUGHTIRONLONG.PROP.S	HOT ROLLED	101
	31	2	27	HAFNIUM	ANNEALED	280	141	2	1	ALUMINUM-WR ALLOY 5056	HARDND H38	100
	70	1	8	NITRIDE STLTYPE : N	WROUGHT	277	25	1	5	INGOT IRON	HOT ROLLED	93
	120	2	16	MONEL 505	CAST	275	144	2	1	ALUMINUM-WR ALLOY 3004	HARDND H38	77
	23	1	4	HI-ALUMINUMALLOY IRON	CAST	265	139	2	1	ALUMINUM-WR ALLOY 5052	HARDND H38	77
	131	1	22	ALLOY STEELCLASS120000	CAST	262	153	2	1	ALUMINUM-WR ALLOY 5086	ANNEALED	75
	14	1	1	GRAY IRON CLASS 60	CAST	260	145	2	1	ALUMINUM-WR ALLOY 5083	ANNEALED	75
*	72	1	8	NITRIDE STLTYPE : E2	WROUGHT	255	132	2	1	ALUMINUM-WR TYPE EC	ANNEALED	75
	51	1	3	MALLEABLE C.I.80002	PEARLITIC	255	112	2	9	TIN BRONZE BBII GR.2A	CAST	75
	13	1	1	GRAY IRON CLASS 50	CAST	238	97	2	2	ALUMINUM ALLOY TYPE319	SAND CAST	70
	4	1	2	CAST IRON 80-60-3	CAST	235	93	2	2	ALUMINUM ALLOY A108	CAST	70
	67	1	8	NITRIDE STL TYPE:135**	WROUGHT	230	24	1	5	INGOT IRON	ANNEALED	69
	57	1	6	CARBON STL. AISI C1095	HARD,GRADE	229	138	2	1	ALUMINUM-WR ALLOY 5052	HARDND H34	68
	50	1	3	MALLEABLE C.I.60003	PEARLITIC	226	95	2	2	ALUMINUM ALLOY 40-E	CAST + AGED	68
	56	1	6	CARBON STL. AISI C1080	HARD,GRADE	223	140	2	1	ALUMINUM-WR ALLOY 5056	ANNEALED	65
	12	1	1	GRAY IRON CLASS 40	CAST	220	157	2	1	ALUMINUM-WR ALLOY 5050	HARDND H38	63
	8	1	2	CAST IRON HEAT RESIST	CAST	220	143	2	1	ALUMINUM-WR ALLOY 3004	HARDND H34	63
	6	1	2	CAST IRON 100-75-04	CAST	220	158	2	1	ALUMINUM-WR ALLOY 5154	ANNEALED	58

49	1	3	MALLEABLE C.I.53004	PEARLITIC	219	136	2	1	ALUMINUM-WR ALLOY 3003	HARDND H18	55
55	1	6	CARBON STL. AISI C1060	HARD,GRADE	212	116	2	11	MG ALLOY ASTM AZ61A-F	FORGED	55
21	1	4	HIGH-SILICAALLOY IRON	CAST	210	156	2	1	ALUMINUM-WR ALLOY 5050	HARDND H34	53
48	1	3	MALLEABLE C.I.50007	PEARLITIC	204	152	2	1	ALUMINUM-WR ALLOY 5005	HARDND H18	51
66	1	6	CARBON STL. AISI C1144	HARD,GRADE	201	117	2	12	MG ALLOY ASTM AZ63A	CAST	50
32	2	27	HAFNIUM	COLD WORKED	200	137	2	1	ALUMINUM-WR ALLOY 5052	ANNEALED	47
37	2	27	VANADIUM	COLD WORKED	197	142	2	1	ALUMINUM-WR ALLOY 3004	ANNEALED	45
129	1	17	STN.STL.-WR AISI 420	ANNEALED	195	73	1	8	NITRIDE STLTYPE:SMI2AL	WROUGHT	44
3	1	1	GRAY IRON CLASS 30	CAST	195	122	2	25	ZINC-ROLLED COMMERCIAL	HOT ROLLED	43
47	1	3	MALLEABLE C.I.48004	PEARLITIC	193	151	2	1	ALUMINUM-WR ALLOY 5005	HARDND H14	41
59	1	6	CARBON STL. AISI C1141	HARD,GRADE	192	135	2	1	ALUMINUM-WR ALLOY 3003	HARDND H14	40
54	1	6	CARBON STL. AISI C1050	HARD,GRADE	192	94	2	2	ALUMINUM ALLOY TYPE 43	CAST	40
119	2	16	INCONEL 610	CAST	190	155	2	1	ALUMINUM-WR ALLOY 5050	ANNEALED	36
46	1	3	MALLEABLE C.I.45007	PEARLITIC	190	149	2	1	ALUMINUM-WR TYPE 1060	HARDND H18	35
22	1	4	HIGH-NICKELALLOY IRON	CAST	190	160	2	1	ALUMINUM-WR TYPE 1100	HARDND H14	32
33	2	27	URANIUM (DEPLETED)	ANNEALED	186	150	2	1	ALUMINUM-WR ALLOY 5005	ANNEALED	28
127	1	16	STN.STL.-WR AISI 405	COLD WORKED	185	134	2	1	ALUMINUM-WR ALLOY 3003	ANNEALED	28
15	1	3	MALLEABLE C.I.GR45010	PEARLITIC	185	148	2	1	ALUMINUM-WR TYPE 1060	HARDND H14	26
53	1	6	CARBON STL. AISI C1040	HARD,GRADE	183	159	2	1	ALUMINUM-WR TYPE 1100	ANNEALED	23
44	2	28	ZIRCALOY-2	@ 600 F.	179	147	2	1	ALUMINUM-WR TYPE 1060	ANNEALED	19
43	2	28	ZIRCALOY-2	@ ROOM TEMP	179	115	2	10	LEAD(1%SB)-WROUGHT	ROLLED	6
40	2	28	ZIRCONIUM--COMMERCIAL	@ 600 F.	179						

LISTING OF THE MATERIALS IN THE CATALOG---PROPERTY LISTED IN THE TABLE BELOW IS:

DENSITY

UNITS : POUNDS/CU.IN.

IN THE TABLE BELOW : COLUMN 1 LISTS THE CATALOG NO
COLUMN 2 LISTS THE CLASS
COLUMN 3 LISTS THE SUBCLASS
COLUMN 6 LISTS THE PROPERTY

FOR OTHER PROPERTIES OF ANY MATERIAL LISTED BELOW
REFER TO THE GENERAL TABLE

1	2	3	MATERIAL NAME	CONDITION	6	1	2	3	MATERIAL NAME	CONDITION	6
101	2	6	TUNGSTEN - WROUGHT	@ ROOM TEMP	700	9	1	2	CAST IRON AUSTENITIC	CAST	268
33	2	27	URANIUM (DEPLETED)	ANNEALED	690	51	1	3	MALLEABLE C.I.80002	PEARLITIC	267
11	1	3	MALLEABLE C.I.GR35018	FERRITIC	610	50	1	3	MALLEABLE C.I.60003	PEARLITIC	267
100	2	6	TANTALUM - WROUGHT	@ ROOM TEMP	600	49	1	3	MALLEABLE C.I.53004	PEARLITIC	267
32	2	27	HAFNIUM	COLD WORKED	470	48	1	3	MALLEABLE C.I.50007	PEARLITIC	267
31	2	27	HAFNIUM	ANNEALED	470	47	1	3	MALLEABLE C.I.48004	PEARLITIC	267
104	2	6	AVC ALLOY -WROUGHT	@ ROOM TEMP	430	46	1	3	MALLEABLE C.I.45007	PEARLITIC	267
35	2	27	THORIUM	COLD WORKED	420	22	1	4	HIGH-NICKELALLOY IRON	CAST	267
34	2	27	THORIUM	ANNEALED	420	15	1	3	MALLEABLE C.I.GR45010	PEARLITIC	267
115	2	10	LEAD(1ESB)-WROUGHT	ROLLED	406	10	1	3	MALLEABLE C.I.GR32510	FERRITIC	261
103	2	6	TIN ALLOY -WROUGHT	@ ROOM TEMP	370	14	1	1	GRAY IRON CLASS 60	CAST	260
102	2	6	MOLYBDENUM WROUGHT	@ ROOM TEMP	370	13	1	1	GRAY IRON CLASS 50	CAST	260
110	2	8	CUPRONICKEL-WR CDA#706	ANNEALED	323	12	1	1	GRAY IRON CLASS 40	CAST	260
28	2	3	COBALT	ROOM TEMP.	320	3	1	1	GRAY IRON CLASS 30	CAST	260
107	2	8	BRONZE - WR CDA #220	ANNEALED	318	122	2	25	ZINC-ROLLED COMMERCIAL	HOT ROLLED	258
112	2	9	TIN BRONZE 8BII GR.2A	CAST	316	7	1	2	CAST IRON 120-90-02	CAST	257
111	2	8	COPPERALLOY-WR CDA#757	ANNEALED	314	6	1	2	CAST IRON 100-75-04	CAST	257
105	2	7	COLUMBIUM -WROUGHT	@ ROOM TEMP	310	5	1	2	CAST IRON 60-45-10	CAST	257
96	2	4	COBALT SUPERALLOY S816	WROUGHT	310	4	1	2	CAST IRON 80-60-3	CAST	257
30	2	3	COBALT AL-LOY : NIVCO	ROOM TEMP.	310	20	1	4	HIGH-SILICAALLOY IRON	CAST	253
92	2	8	BRASS--FREE CUTTING	HARD	307	21	1	4	HIGH-SILICAALLOY IRON	CAST	250
91	2	8	BRASS--FREE CUTTING	ANNEALED	307	8	1	2	CAST IRON HEAT RESIST	CAST	250
90	2	8	ARCH.BRONZE CKA # 385	ANNEALED	306	2	1	1	GRAY IRON CLASS 25	CAST	250
106	2	7	B-66 ALLOY WROUGHT	@ ROOM TEMP	305	1	1	1	GRAY IRON CLASS 20	CAST	250
89	2	8	BRASS-FORGE CDA # 377	ANNEALED	305	45	2	28	ZIRCONIUM--TYPE 1 ATR	@ 600 F.	240
109	2	8	NAVAL BRASS-WR CDA#467	ANNEALED	304	44	2	28	ZIRCALOY-2	@ 600 F.	237
88	2	8	MUNTZ METALFREE-CUTTIN	HARD	304	43	2	28	ZIRCALOY-2	@ ROOM TEMP	237
87	2	8	MUNTZ METALFREE-CUTTIN	ANNEALED	304	40	2	28	ZIRCONIUM--COMMERCIAL	@ 600 F.	237
108	2	8	MUNTZ METAL-WR CDA#280	ANNEALED	303	39	2	28	ZIRCONIUM--COMMERCIAL	@ ROOM TEMP	237
120	2	16	MONEL 505	CAST	302	42	2	28	ZIRCONIUM--REACTOR GR.	@ 600 F.	235
119	2	16	INCONEL 610	CAST	300	41	2	28	ZIRCONIUM--REACTOR GR.	@ ROOM TEMP	235
99	2	5	COBALT SUPERALLOY HS21	INVEST.CAST	300	37	2	27	VANADIUM	COLD WORKED	230
118	2	15	DURANICKEL-WR TYPE 301	ANNEALED	298	36	2	27	VANADIUM	ANNEALED	230
29	2	3	COBALT AL-LOY:UMCO-50	ROOM TEMP.	291	23	1	4	HI-ALUMINUMALLOY IRON	CAST	216
126	1	15	STN.STL.-WR AISI 321	ANNEALED	290	121	2	24	TITANIUM ALLOY 7AL-4MO	WR.@ROOM T.	162
125	1	15	STN.STL.-WR AISI 316	ANNEALED	290	113	2	9	YELLOWBRASS 8BII GR.6B	CAST	112
124	1	15	STN.STL.-WR AISI 301	ANNEALED	290	93	2	2	ALUMINUM ALLOY A108	CAST	101
131	1	22	ALLOY STEELCLASS120000	CAST	283	95	2	2	ALUMINUM ALLOY 40-E	CAST + AGED	100
130	1	21	CARBON STL.CLASS 60000	ANNEALED	283	136	2	1	ALUMINUM-WR ALLOY 3003	HARDND H18	99
123	1	13	STEEL - WR AISI B1112	FREE-CUTTIN	283	135	2	1	ALUMINUM-WR ALLOY 3003	HARDND H14	99
73	1	8	NITRIDE STLTYPE:SNI2AL	WROUGHT	283	134	2	1	ALUMINUM-WR ALLOY 3003	ANNEALED	99
* 72	1	8	NITRIDE STLTYPE : EZ	WROUGHT	283	160	2	1	ALUMINUM-WR TYPE 1100	HARDND H14	98
71	1	8	NITRIDE STLTYPE : N*	WROUGHT	283	159	2	1	ALUMINUM-WR TYPE 1100	ANNEALED	98
70	1	8	NITRIDE STLTYPE : N	WROUGHT	283	149	2	1	ALUMINUM-WR TYPE 1060	HARDND H18	98

*	69	1	8	NITRIDE STLTYPE:135MD	WROUGHT	283	148	2	1	ALUMINUM-WR TYPE 1060	HAROND H14	98
	68	1	8	NITRIDE STLTYPE:135MD	WROUGHT	283	147	2	1	ALUMINUM-WR TYPE 1060	ANNEALED	98
*	67	1	8	NITRIDE STL TYPE:135	WROUGHT	283	144	2	1	ALUMINUM-WR ALLOY 3004	HAROND H38	98
	66	1	8	NITRIDE STL TYPE:135	WROUGHT	283	143	2	1	ALUMINUM-WR ALLOY 3004	HARDND H34	98
	65	1	7	CARBON STL. AISI C1118	CARBURIZING	283	142	2	1	ALUMINUM-WR ALLOY 3004	ANNEALED	98
	64	1	7	CARBON STL. AISI C1117	CARBURIZING	283	133	2	1	ALUMINUM-WR TYPE EC	HARDND H19	98
	63	1	7	CARBON STL. AISI C1022	CARBURIZING	283	132	2	1	ALUMINUM-WR TYPE EC	ANNEALED	98
	62	1	7	CARBON STL. AISI C1020	CARBURIZING	283	157	2	1	ALUMINUM-WR ALLOY 5050	HARDND H38	97
	61	1	7	CARBON STL. AISI C1015	CARBURIZING	283	156	2	1	ALUMINUM-WR ALLOY 5050	HARDND H34	97
	57	1	6	CARBON STL. AISI C1095	HARD.GRADE	283	155	2	1	ALUMINUM-WR ALLOY 5050	ANNEALED	97
	56	1	6	CARBON STL. AISI C1080	HARD.GRADE	283	152	2	1	ALUMINUM-WR ALLOY 5005	HARDND H18	97
	55	1	6	CARBON STL. AISI C1060	HARD.GRADE	283	151	2	1	ALUMINUM-WR ALLOY 5005	HARDND H14	97
	54	1	6	CARBON STL. AISI C1050	HARD.GRADE	283	150	2	1	ALUMINUM-WR ALLOY 5005	ANNEALED	97
	53	1	6	CARBON STL. AISI C1040	HARD.GRADE	283	139	2	1	ALUMINUM-WR ALLOY 5052	HARDND H38	97
	52	1	6	CARBON STL. AISI C1030	HARD.GRADE	283	138	2	1	ALUMINUM-WR ALLOY 5052	HARDND H34	97
	60	1	6	CARBON STL. AISI C1144	HARD.GRADE	282	137	2	1	ALUMINUM-WR ALLOY 5052	ANNEALED	97
	59	1	6	CARBON STL. AISI C1141	HARD.GRADE	282	97	2	2	ALUMINUM ALLOY TYPE319	SAND CAST	97
	58	1	6	CARBON STL. AISI C1137	HARD.GRADE	282	96	2	2	ALUMINUM ALLOY A380	DIE CAST	97
	114	2	9	ALUM.BRONZE BRIT GR.9A	SAND CAST	281	94	2	2	ALUMINUM ALLOY TYPE 43	CAST	97
	129	1	17	STN.STL.-WR AISI 420	ANNEALED	280	158	2	1	ALUMINUM-WR ALLOY 5154	ANNEALED	96
	128	1	17	STN.STL.-WR AISI 410	ANNEALED	280	154	2	1	ALUMINUM-WR ALLOY 5086	HARDND H34	96
	127	1	16	STN.STL.-WR AISI 405	COLD WORKED	280	153	2	1	ALUMINUM-WR ALLOY 5086	ANNEALED	96
	26	1	5	INGOT IRON	COLD DRAWN	280	146	2	1	ALUMINUM-WR ALLOY 5083	HARDND H113	96
	25	1	5	INGOT IRON	HOT ROLLED	280	145	2	1	ALUMINUM-WR ALLOY 5083	ANNEALED	96
	24	1	5	INGOT IRON	ANNEALED	280	141	2	1	ALUMINUM-WR ALLOY 5056	HARDND H38	95
	19	1	4	MOLYBDENUM ALLOY IRON	CAST	280	140	2	1	ALUMINUM-WR ALLOY 5056	ANNEALED	95
	27	1	5	WROUGHTIRONLONG.PROP.S	HOT ROLLED	278	38	2	27	BERYLLIUM	ANNEALED	67
	17	1	4	NICKEL-HARDALLOY IRON	CAST	278	117	2	12	MG ALLOY ASTM AZ63A	CAST	66
	16	1	4	WHITE IRON	CAST	278	116	2	11	MG ALLOY ASTM AZ61A-F	FORGED	65
	18	1	4	HIGH CHROMEALLOY IRON	CAST	272						

AN ALPHABETICAL LISTING OF THE MATERIALS IN THE CATALOG

IN THE TABLE BELOW : COLUMN 1 LISTS THE CATALOG NO
COLUMN 2 LISTS THE CLASS
COLUMN 3 LISTS THE SUBCLASS

FOR ALL THEPROPERTIES OF ANY MATERIAL LISTED BELOW
REFER TO THE GENERAL TABLE

1	2	3	MATERIAL NAME	1	2	3	MATERIAL NAME	1	2	3	MATERIAL NAME
84	1	10	*LLOY STEEL AISI 9255	92	2	8	BRASS--FREE CUTTING	49	1	3	MALLEABLE C.I.53004
75	1	10	ALLOY STEEL AISI 3110	89	2	8	BRASS-FORGE CDA # 377	50	1	3	MALLEABLE C.I.60003
86	1	10	ALLOY STEEL AISI 4063	107	2	8	BRONZE - WR CDA #220	51	1	3	MALLEABLE C.I.80002
74	1	10	ALLOY STEEL AISI 4130	61	1	7	CARBON STL. AISI C1015	10	1	3	MALLEABLE C.I.GR32510
76	1	10	ALLOY STEEL AISI 4140	62	1	7	CARBON STL. AISI C1020	11	1	3	MALLEABLE C.I.GR35018
80	1	10	ALLOY STEEL AISI 4150	63	1	7	CARBON STL. AISI C1022	15	1	3	MALLEABLE C.I.GR45010
77	1	10	ALLOY STEEL AISI 4340	52	1	6	CARBON STL. AISI C1030	117	2	12	MG ALLOY ASTM AZ63A
78	1	10	ALLOY STEEL AISI 5140	53	1	6	CARBON STL. AISI C1040	116	2	11	MG ALLOY ASTM AZ61A-F
81	1	10	ALLOY STEEL AISI 5150	54	1	6	CARBON STL. AISI C1050	19	1	4	MOLYBDENUM ALLOY IRON
85	1	10	ALLOY STEEL AISI 5160	55	1	6	CARBON STL. AISI C1060	102	2	6	MOLYBDENUM WROUGHT
82	1	10	ALLOY STEEL AISI 6150	56	1	6	CARBON STL. AISI C1080	120	2	16	MONEL 505
83	1	10	ALLOY STEEL AISI 8650	57	1	6	CARBON STL. AISI C1095	108	2	8	MUNTZ METAL-WR CDA#280
79	1	10	ALLOY STEEL AISI 8740	64	1	7	CARBON STL. AISI C1117	87	2	8	MUNTZ METALFREE-CUTTIN
131	1	22	ALLOY STEELCLASS120000	65	1	7	CARBON STL. AISI C1118	88	2	8	MUNTZ METALFREE-CUTTIN
114	2	9	ALUM.BRONZE BBII GR.9A	58	1	6	CARBON STL. AISI C1137	109	2	8	NAVAL BRASS-WR CDA#467
93	2	2	ALUMINUM ALLOY A108	59	1	6	CARBON STL. AISI C1141	17	1	4	NICKEL-HARDALLOY IRON
96	2	2	ALUMINUM ALLOY A380	60	1	6	CARBON STL. AISI C1144	66	1	8	NITRIDE STL TYPE#135
94	2	2	ALUMINUM ALLOY TYPE 43	130	1	21	CARBON STL.CLASS 60000	67	1	8	NITRIDE STL TYPE#135
97	2	2	ALUMINUM ALLOY TYPE319	4	1	2	CAST IRON 80-60-3	72	1	8	NITRIDE STLTYPE # EZ
95	2	2	ALUMINUM ALLOY 40-E	5	1	2	CAST IRON 60-45-10	70	1	8	NITRIDE STLTYPE # N
132	2	1	ALUMINUM-WR TYPE EC	6	1	2	CAST IRON 100-75-04	71	1	8	NITRIDE STLTYPE # N*
133	2	1	ALUMINUM-WR TYPE EC	7	1	2	CAST IRON 120-90-02	68	1	8	NITRIDE STLTYPE#135MD
147	2	1	ALUMINUM-WR TYPE 1060	9	1	2	CAST IRON AUSTENITIC	69	1	8	NITRIDE STLTYPE#135MD
148	2	1	ALUMINUM-WR TYPE 1060	8	1	2	CAST IRON HEAT RESIST	73	1	8	NITRIDE STLTYPE#5NI2AL
149	2	1	ALUMINUM-WR TYPE 1060	28	2	3	COBALT	123	1	13	STEEL - WR AISI B1112
159	2	1	ALUMINUM-WR TYPE 1100	30	2	3	COBALT AL-LOY # NIVCO	124	1	15	STN.STL.-WR AISI 301
160	2	1	ALUMINUM-WR TYPE 1100	29	2	3	COBALT AL-LOY#UMCO-50	125	1	15	STN.STL.-WR AISI 316
134	2	1	ALUMINUM-WR ALLOY 3003	99	2	5	COBALT SUPERALLOY HS21	126	1	15	STN.STL.-WR AISI 321
135	2	1	ALUMINUM-WR ALLOY 3003	98	2	4	COBALT SUPERALLOY S816	127	1	16	STN.STL.-WR AISI 405
136	2	1	ALUMINUM-WR ALLOY 3003	105	2	7	COLUMBIUM -WROUGHT	128	1	17	STN.STL.-WR AISI 410
142	2	1	ALUMINUM-WR ALLOY 3004	111	2	8	COPPERALLOY-WR CDA#757	129	1	17	STN.STL.-WR AISI 420
143	2	1	ALUMINUM-WR ALLOY 3004	110	2	8	CUPRONICKEL-WR CDA#706	100	2	6	TANTALUM - WROUGHT
144	2	1	ALUMINUM-WR ALLOY 3004	118	2	15	DURANICKEL-WR TYPE 301	34	2	27	THORIUM
150	2	1	ALUMINUM-WR ALLOY 5005	1	1	1	GRAY IRON CLASS 20	35	2	27	THORIUM
151	2	1	ALUMINUM-WR ALLOY 5005	2	1	1	GRAY IRON CLASS 25	112	2	9	TIN BRONZE BBII GR.2A
152	2	1	ALUMINUM-WR ALLOY 5005	3	1	1	GRAY IRON CLASS 30	121	2	24	TITANIUM ALLOY 7AL-4MO
155	2	1	ALUMINUM-WR ALLOY 5050	12	1	1	GRAY IRON CLASS 40	101	2	6	TUNGSTEN - WROUGHT
156	2	1	ALUMINUM-WR ALLOY 5050	13	1	1	GRAY IRON CLASS 50	103	2	6	TZM ALLOY -WROUGHT
157	2	1	ALUMINUM-WR ALLOY 5050	14	1	1	GRAY IRON CLASS 60	33	2	27	URANIUM (DEPLETED)
137	2	1	ALUMINUM-WR ALLOY 5052	31	2	27	HAFNIUM	36	2	27	VANADIUM
138	2	1	ALUMINUM-WR ALLOY 5052	32	2	27	HAFNIUM	37	2	27	VANADIUM
139	2	1	ALUMINUM-WR ALLOY 5052	23	1	4	NI-ALUMINUMALLOY IRON	16	1	4	WHITE IRON
140	2	1	ALUMINUM-WR ALLOY 5056	18	1	4	HIGH CHROMEALLOY IRON	27	1	5	WROUGHTIRONLONG.PROP.5
141	2	1	ALUMINUM-WR ALLOY 5056	22	1	4	HIGH-NICKELALLOY IRON	113	2	9	YELLOWBRASS BBII GR.6B
145	2	1	ALUMINUM-WR ALLOY 5083	20	1	4	HIGH-SILICAALLOY IRON	122	2	25	ZINC-ROLLED COMMERCIAL
146	2	1	ALUMINUM-WR ALLOY 5083	21	1	4	HIGH-SILICAALLOY IRON	43	2	28	ZIRCALOY-2
153	2	1	ALUMINUM-WR ALLOY 5086	119	2	16	INCONEL 610	44	2	28	ZIRCALOY-2
154	2	1	ALUMINUM-WR ALLOY 5086	24	1	5	INGOT IRON	39	2	28	ZIRCONIUM--COMMERCIAL
158	2	1	ALUMINUM-WR ALLOY 5154	25	1	5	INGOT IRON	40	2	28	ZIRCONIUM--COMMERCIAL

90	2	8	ARCH.BRONZE CKA # 385	26	1	5	INGOT IRON	41	2	28	ZIRCONIUM--REACTOR GR.
104	2	6	AVC ALLOY -WROUGHT	115	2	10	LEAD(1$SB)-WROUGHT	42	2	28	ZIRCONIUM--REACTOR GR.
106	2	7	B-66 ALLOY WROUGHT	46	1	3	MALLEABLE C.I.45007	45	2	28	ZIRCONIUM--TYPE 1 ATR
38	2	27	BERYLLIUM	47	1	3	MALLEABLE C.I.48004				
91	2	8	BRASS--FREE CUTTING	48	1	3	MALLEABLE C.I.50007				

CHOICE	REQUEST #0	1ST CHOICE	2ND CHOICE	3RD CHOICE	REQUEST #1	1ST CHOICE	2ND CHOICE	3RD CHOICE
DESIRABILITY	100 %	99 %	00 %	00 %	100 %	89 %	44 %	63 %
CATALOG NUMBER		141				20	76	79

CHOICE	REQUEST #2	1ST CHOICE	2ND CHOICE	3RD CHOICE	REQUEST #3	1ST CHOICE	2ND CHOICE	3RD CHOICE
DESIRABILITY	100 %	92 %	00 %	00 %	100 %	88 %	41 %	41 %
CATALOG NUMBER		31				37	86	85

CHOICE	REQUEST #4	1ST CHOICE	2ND CHOICE	3RD CHOICE	* REQUEST #5	* 1ST CHOICE	* 2ND CHOICE	* 3RD CHOICE
DESIRABILITY	100 %	85 %	82 %	81 %	100 %	94 %	89 %	87 %
CATALOG NUMBER		65	64	63		72	66	69
					*	*	*	*

APPENDIX D

COMPUTER PROGRAM LISTING

A listing of the computer program developed for this system is included in the following pages. Below is a brief breakdown of the program, identified by the statement numbers.

Statements 1-1 through 8-30 are identification, environment, and data divisions. Highlighting these divisions; statements 1-17* through 1-28 are the input card file, 1-29 through 1-337 are the output report file, 1-34 through 1-40 are the sort file. Working storage starts at statement 1-41 and its highlights are Materials Data File (2-1 through 2-17), Listing Request Card (2-18 through 2-21), Selection Request Card (2-22 through 2-39), Error Messages (5-1 through 5-65), and output formats (6-1 through 8-30).

The procedure division starts at statement 10-1 and continues with Card Read and Edit Section (through 10-405), Table Headers (10-41 through 10-72), sort section (11-1 to 11-25), Property Listings (11-26 through 12-22), Matrix Manupilation and Decision Calculations (12-50 through 14-13), Selection (14-16) and Composite Property Calculations (through 14-58), Sort Processing sections (15-1 to 15-66), Catalog (16-1 to 17-49) and Selection (18-1 to 19-99) Listing Sections, and concludes with a calculation of the processing time requirements (20-1 to 20-3).

Interrelationships of various sections are shown in Figures 4 and 5.

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*Numbers referred are statement numbers.

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B 5 5 0 0   C O B O L   C O M P I L E R ,     D I S K    FRIDAY
 USER= 8799139, BIN 0394
 COMPILE 91=0394/ORGAN   COBOL        .225000007   +0394 ALTIN
 PROCESS=0015;IO=0004;COBOL   PROCESS=15;COBOL   IO=15.
 DATA.
 DATA CASENT .
IDENTIFICATION DIVISION.
PROGRAM-ID. COMPUTER AIDED SELECTION OF ENGINEERING MATERIALS .
AUTHOR. VEFIK NEZIH DIVITCI.
DATE WRITTEN; APRIL 1967 .
DATE-COMPILED.   8-19-68,  4:29 AM.
ENVIRONMENT DIVISION.
CONFIGURATION SECTION.
SOURCE-COMPUTER. B-5500.
OBJECT-COMPUTER. B-5500.
INPUT-OUTPUT SECTION.
FILE-CONTROL.
    SELECT CARDF         ASSIGN TO READER
    SELECT PRINTOUT      ASSIGN TO PRINTER DISK
    SELECT SORTFILE1     ASSIGN TO SORT DISK.
DATA DIVISION. PREPARED FOR B-5500.
FILE SECTION.
FD  CARDF
    LABEL RECORD IS STANDARD
    VALUE OF ID IS "CASEHI"
    DATA RECORD IS CARDFORMAT.
01  CARDFORMAT.
    02 OPTION PC 9.
    02 REST.
        03 RESTCARD.
            04 REST1 SZ 20.
            04 REST2 SZ 30.
        03 DMP1 SZ 24.
        03 CRDNU PC 9(5).
FD  PRINTOUT
    LABEL RECORDS ARE STANDARD
    VALUE OF ID IS "CASEHIT"
    DATA RECORDS ARE PRINTBLANK.
01  PRINTBLANK SZ 120.
    02 FILLER SZ 24.
    02 PRRK SZ 72.
    02 FILLER SZ 24.
SD  SORTFILE1 ; DATA RECORD IS SORTREC.
01  SORTREC.
    02 SRTCLS PC 9.
    02 SRTSCL PC 99.
    02 MATNO1  PC 999.
    02 PVALUE  PC 9999.
    02 SRTNM PC X(25).
WORKING-STORAGE SECTION.
01  A  PC 999.
01  AA PC 999.
01  AAA PC 999.
01  B  PC 99.
01  BB PC 999.
01  BBB PC 99.
01  BLNKS SZ 11 VA SPACES .
01  BLNKS1 SZ 22 VA SPACES .
01  CONT PC 9.
01  CT1  PC 99.
01  CTL8 PC 9.
01  CTR1 PC 999.
01  CTR2 PC 999.
01  DMP  PC 9.
01  DUMMY1 PC 999.
01  DUMMY2 PC 999.
01  I PC 99.
01  II PC 99.
01  III PC 999.
01  J PC 999.
01  JJ PC 999.
01  JJJ PC 999.
01  K PC 999.
01  KK PC 99.
01  KKK PC 999.
01  L PC 999.
01  L9 PC 9.
01  LL PC 99.
01  LX1 PC 9.
01  M PC 99.
01  N PC 999.
01  SUB PC 9999.
01  KCTN PC 9.
01  X PC 9.
01  Y PC 99.
01  ACTUAL-TIME.
    02 ATT1 SZ 24.
    02 ATT PC 99999,99999.
    02 FILLER SZ 84 VA SPACES.
01  MTLDTGEN1.
    02 MTLDT1 OCCURS 160 TIMES.
        03 KCLASS   PC  9.
        03 SUBCLASS PC 99.
        03 PROPERTY OCCURS 13; PC 999.
        03 PROPERTY OCCURS 2; PC 9999.
01  MTLDTGEN2.
    02 MTLDT2 OCCURS 160 TIMES.
        03 NAME   SZ 25.
        03 CONDTN SZ 11.
        03 CORROSION OC 6; PC 9.
        03 PROPERTY  OC 21 PC 99.
        03 PROPERTY  OC 4; PC 9.
01  MTLDTGEN3.
    02 MTLDT3 OCCURS 160 TIMES.
        03 COMPROPY  OC 4; PC  9V999.
        03 CRDNO PC 9(5).
01  DMPCRD.
    02 DMPKEY1 OCCURS 17; PC 9.
    02 SCLASS PC 99.
    02 STABLE PC 9.
01  DESVRBLS.
    02 DESVAR OCCURS 9.
        03 FIELD OCCURS 5.
            04 PRPRTY PC 99.
            04 IMPRTN PC  9.
            04 MAXMIN PC  9.
            04 RESVAL PC 9(4).
        03 FIELD OCCURS 4 TIMES.
            04 PRVN  PC  99.
            04 IMPS  PC  9.
            04 RTNG  PC  99.
        03 FIELD OC 3.
            04 PVD  PC  9.
            04 IMP  PC  9.
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            [illegible] 9.
            04 RAVL PC 999.
        03 REQUESTNO PC    9.
 01  MATRICES.
     02 MATRIX OCCURS 50.
        03 MATNO PC 999.
        03 VALT OC 12; PC 99V999.
        03 SUM1 PC 999V999.
 01  SOLUTION.
     02 SOL1 OC 9.
        03 SOL2 OC 5.
            04 SOL OC 10; PC 999.
 01  ANSWERS.
     02 ANSWER1 OC 9.
        03 ANSWER2 OC 3.
            04 MTL PC 999.
            04 DES PC 9999V999.
        03 SUM2 PC 999V999.
        03 SUM3 PC 999V999.
        03 SUM4 PC 999V999.
 01  ORG-REQ.
     02 ORG-REQ1  OC  15.
        03  PNR  PC 9.
        03  RNR  OC  9 ; PC 9.
 01  TABLEOUT.
     02 ST21 PC X; VA "*".
     02 ROW-TITLE PC X(22).
     02 ST22 PC X; VA "*".
     02 COLUMN OC 8.
        03 COLUMN-FIELD PC X(11).
        03 ST20 PC X.
 01  ROW-LINES.
     02 RWLN1 PC X(22); VA "----------------------".
     02 RWLN2.
        03 RWLN21 PC X(3).
        03 RWLN22 PC X(19); VA "-------------------".
     02 RWLN3.
        03 RWLN31 PC X(7).
        03 RWLN32 PC X(15); VA "---------------".
     02 RWLN4 PC X(11); VA "-----------".
 01  WORK-AREA1 SZ 22.
     02 WA11 PC X(3).
     02 WA12.
        03 WA13 PC X(4).
        03 WA14 PC X(15).
 01  WORK-AREA2.
     02 WA21.
        03 FILLER SZ 4 VA SPACES .
        03 WA211 PC 999 ; ZS BLANK WHEN ZERO.
        03 FILLER SZ 4 VA SPACES .
     02 WA22.
        03 WA221 PC X(11).
        03 WA222 PC X(3).
        03 WA223 PC X(11).
     02 WA23.
        03 FILLER SZ 5 VA SPACES .
        03 WA231 PC 9 ; ZS BLANK WHEN ZERO.
        03 FILLER SZ 5 VA SPACES .
     02 WA24.
        03 FILLER SZ 3 VA SPACES .
        03 WA241 PC 9999 ; ZS BLANK WHEN ZERO.
        03 FILLER SZ 4 VA SPACES .
     02 WA25.
        03 WA251 PC X(11).
        03 WA252 PC X(11).
     02 WA26.
        03 FILLER SZ 9 VA "REQUEST #".
        03 WA261 PC 9.
     02 WA27.
        03 FILLER SZ 3 VA SPACES.
        03 WA271 PC 9V99 ; ZS.
        03 FILLER SZ 5 VA " % ".
     02 WA28.
        03 WA281 PC 999 ; ZS BLANK WHEN ZERO.
        03 FILLER SZ 2 VA " (".
        03 WA282 PC 9.
        03 FILLER SZ 1 VA ",".
        03 WA283 PC X.
        03 FILLER SZ 1 VA ")".
 01  HONGARRAY.
     02 HONG OC 151 PC X(36).
 01  UNITARRAY.
     02 UNIT OC 151 PC X(15).
 01  SRTPROP1.
     02 SRTPROP11 OCCURS 160 TIMES.
        03 SRTCLS1 PC  9.
        03 SRTSCL1 PC 99.
        03 NNO1 PC 999.
        03 PROP PC 9999.
        03 SRTNM1  PC X(25).
 01  DUMP1BLNK.
     02 DMP1BLNK OC 2.
        03 FILLER SZ 1.
        03 STAR1 PC X.
        03 CTNO  PC 999.
        03 STAR2 PC X.
        03 CL1 PC 9.
        03 STAR3 PC X.
        03 SCL1 PC 99.
        03 STAR4 PC X.
        03 NAMEOUT  PC X(25).
        03 STAR5 PC X.
        03 CNNOOUT  PC X(11).
        03 STAR6 PC X.
        03 PROPOUT  PC 9(4).
        03 STAR7 PC X.
        03 FILLER SZ 4.
 01  DUMP2BLNK.
     02 DMP2BLNK OC 3.
        03 FILLER SZ 3.
        03 STAR11 PC X.
        03 NAMEOUT2 PC X(25).
        03 STAR8 PC X.
        03 SCL2 PC 99.
        03 STAR9 PC X.
        03 CL2 PC 9.
        03 STAR0 PC X.
        03 CTNO2 PC 999.
        03 STAR10 PC X.
        03 FILLER SZ 3.
 01  DUMP3BLNK.
     02 DMP3BLNK OC 2.
        03 FILLER SZ 1.
        03 STAR12 PC X.
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          03 CYNO3 PC 999.
          03 STAR13 PC X.
          03 CL3 PC 9.
          03 STAR14 PC X.
          03 SCL3 PC 99.
          03 STAR15 PC X.
          03 NAMEOUT3 PC X(25).
          03 STAR16 PC X.
          03 CONDOUT3 PC X(11).
          03 STAR17 PC X.
          03 PROPOUT3 PC 9(6).
          03 STAR18 PC X.
          03 RTNGOUT3 PC 99.
          03 STAR19 PC X.
          03 FILLER SZ 1.
 01  TITLE16.
     02 TITLE161 OC 2.
          03 TTL26.
               04 ST1 PC X.
               04 FILLER SZ 1.
               04 CATNO9 PC 999 ; ZS BLANK WHEN ZERO.
               04 FILLER SZ 1.
               04 ST2 PC X.
               04 FILLER SZ 1.
               04 CLS9 PC 9 ; ZS BLANK WHEN ZERO.
               04 FILLER SZ 1.
               04 ST3 PC X.
               04 FILLER SZ 1.
               04 SCL9 PC 99 ; ZS BLANK WHEN ZERO.
               04 FILLER SZ 1.
               04 ST4 PC X.
               04 FILLER SZ 1.
               04 MTLNM9 PC X(22).
               04 ST5 PC X.
               04 FILLER SZ 1.
               04 CNDTN9 PC X(11).
               04 ST6 PC X.
               04 FILLER SZ 1.
               04 PRP9O PC 9(4); ZS BLANK WHEN ZERO.
               04 FILLER SZ 1.
               04 ST7 PC X.
 01  TITLE17.
     02 TITLE171 OC 3.
          03 TTL27.
               04 ST8 PC X.
               04 FILLER SZ 1.
               04 CATNO8 PC 999 ; ZS BLANK WHEN ZERO.
               04 FILLER SZ 1.
               04 ST9 PC X.
               04 FILLER SZ 1.
               04 CLS8 PC 9 ; ZS BLANK WHEN ZERO.
               04 FILLER SZ 1.
               04 ST10 PC X.
               04 FILLER SZ 1.
               04 SCL8 PC 99 ; ZS BLANK WHEN ZERO.
               04 FILLER SZ 1.
               04 ST11 PC X.
               04 FILLER SZ 1.
               04 MTLNM8 PC X(22).
               04 ST12 PC X.
 01  ERR.
     02 FILLER SZ 39 VA "XXXXXX WARNING FLAG=DATA SECTION  :    ".
     02 ERR1  PC XXX.
     02 FILLER SZ 37  VA " CARD MISSING, THEREFORE CARD NUMBER ".
     02 ERR2  PC 9(5).
     02 FILLER SZ 37 VA "  IS EXCLUDED FROM THE CATALOG.      ".
 01  ERR5 SZ 120 VA "XXXXXX WARNING FLAG=DATA SECTION  :   THE FOL
-    "LOWING CARD IS UNIDENTIFIED, THEREFORE NOT PROCESSED  :
-    "              ".
 01  ERR6 .
     02 FILLER SZ 38 VA SPACES.
     02 ERR61 PC X(80).
     02 FILLER SZ 2 VA SPACES.
 01  ERR7 SZ 120 VA "XXXXXX WARNING FLAG=DATA SECTION  :  CATALOG
-    "DATA SUPPLIED EXCEEDS STORAGE CAPACITY,THUS ONLY 1ST 160 MAT
-    "ERIALS ARE USED".
 01  ERR8.
     02 FILLER SZ 55 VA "                                          FILE
-    "NO.CARD NUMBER ".
     02 ERR75 PC 9(5).
     02 FILLER SZ 67 VA " AND ALL MATERIALS DATA FOLLOWING THIS CA
-    "RD IS OMITTED.      ".
 01  ERR9 SZ 120 VA "XXXXXX WARNING FLAG-DATA SECTION  :   THE LIS
-    "TING REQUEST CARD BELOW IS REJECTED ; DO NOT COMPILE MORE TH
-    "AN ONE:           ".
 01  ERR0 SZ 120 VA "XXXXXX WARNING FLAG-DATA SECTION  :   THE SEL
-    "ECTION REQUEST CARD BELOW IS REJECTED, DO NOT COMPILE MORE T
-    "HAN NINE:         ".
 01  JOB1.
     02 FILLER SZ 62 VA "      PROGRAM AND DATA HAS BEEN COMPILED.
-    "CATALOG CONSISTS OF  ".
     02 J2 PC 999.
     02 FILLER SZ 40 VA "  ITEMS                                  ".
     02 FILLER SZ 16 VA SPACES.
 01  JOB2 SZ 120 VA "      EXECUTION REQUESTED BUT CATALOG NOT SUPP
-    "LIED THEREFORE THIS COMPUTER RUN IS SUSPENDED: SUPPLY CATALO
-    "G WITH NEXT RUN".
 01  JOB3 SZ 120 VA "      SUPPLIED CATALOG HAS BEEN READ IN AND FI
-    "LED--EXECUTION TERMINATED SINCE NEITHER LISTING NOR SELECTIO
-    "N IS REQUESTED ".
 01  JOB4.
     02 FILLER SZ 24   VA "XXXXXXX PROGRAM MESSAGE:".
     02 FILLER SZ 96 VA SPACES.
 01  TITLE1 SZ 120 VA "                         LISTING OF THE MATERIAL
-    "S IN THE CATALOG---PROPERTY LISTED IN THE TABLE BELOW IS:
-    "                     ".
 01  TITLE2.
     02 FILLER SZ 42 VA SPACES .
     02 PROPTTL PC X(36).
     02 FILLER SZ 42 VA SPACES.
 01  TITLE3.
     02 FILLER SZ 49 VA SPACES .
     02 UNT.
          03 UNT1 PC X(8); VA "UNITS : ".
          03 TTLUNIT PC X(15).
     02 FILLER SZ 49 VA SPACES.
 01  TITLE4 SZ 120 VA "                                          IN THE T
-    "ABLE BELOW : COLUMN 1 LISTS THE CATALOG NO
-    "                    ".
 01  TITLE5 SZ 120 VA "
-    "               COLUMN 2 LISTS THE CLASS
-    "                    ".
 01  TITLE6 SZ 120 VA "
-    "               COLUMN 3 LISTS THE SUBCLASS
```

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-          "                          ".
       01  TITLE7 SZ 120 VA "
-          "                 COLUMN 6 LISTS THE PROPERTY
-          "                          ".
       01  TITLE8.
           02 FILLER SZ 39 VA "                                       FOR ".
           02 TTL7 PC X(7).
           02 FILLER SZ 40 VA "PROPERTIES OF ANY MATERIAL LISTED BELOW".
           02 FILLER SZ 35 VA SPACES.
       01  TITLE9 SZ 120 VA "                                      REFER TO
-          "THE GENERAL TABLE
-          "                          ".
       01  TITLE10.
           02 FILLER SZ 36    VA "*  1  * 2 *  3 * MATERIAL NAME        ".
           02 FILLER SZ 35  : VA "    * CONDITION  *   6  **  1  * 2 * ".
           02 FILLER SZ 36    VA " 3 * MATERIAL NAME              * CONDITI".
           02 FILLER SZ 12    VA "ON   *    6  *".
       01  TITLE11 SZ 120 VA "                                      AN ALPHAB
-          "ETICAL LISTING OF THE MATERIALS IN THE CATALOG
-          "                          ".
       01  TITLE12 SZ 120 VA "*  1  * 2 *  3 * MATERIAL NAME           **
-          " 1  * 2 *  3 * MATERIAL NAME            **  1  * 2 *  3 * MATER
-          "IAL NAME          *".
       01  TITLE13 SZ 120 VA "                                      A LISTI
-          "NG OF MATERIALS IN THE CATALOG BELONGING TO:
-          "                          ".
       01  TITLE14.
           02 FILLER SZ 43 VA "
-          "                CLASS : ".
           02 TTL23 PC 9.
           02 FILLER SZ 56 VA SPACES.
       01  TITLE15.
           02 FILLER SZ 63 VA "
-          "                SUBCLASS : ".
           02 TTL25 PC 99.
           02 FILLER SZ 55 VA SPACES.
       01  GENTABLE1 SZ 120 VA "
-          "                 GENERAL TABLE
-          "                          ".
       01  GENTABLE2 SZ 120 VA "                                   A LISTING OF
-          "ALL MATERIALS AND PROPERTIES COMPILED IN THE CATALOG
-          "                          ".
       01  GENTABLE3 SZ 120 VA "
-          "     -IN THE ORDER OF COMPILATION-
-          "                          ".
       01  GENTABLE4 SZ 120 VA "                             NOTES : 1-CLASSES
-          "1 AND 2 INDICATE FERROUS AND NON-FERROUS METALS RES-
-          "                          ".
       01  GENTABLE5 SZ 120 VA "                                     PECTIVEL
-          "Y; FOR A DISCUSSION OF SUBCLASSES REFER TO THE TEXT.
-          "                          ".
       01  GENTABLE6 SZ 120 VA "                                    2-VALUES L
-          "ISTED FOR FATIGUE ARE ENDURANCE LIMITS GIVEN IN KSI.
-          "                          ".
       01  GENTABLE61 SZ 120 VA "                                   3-VALUES
-          "FOR MACHINABILITY ARE BASED ON AISI B1112 = 100.
-          "                          ".
       01  GENTABLE7 SZ 120 VA "                                    4-ALL RATI
-          "NGS ARE RELATIVE VALUES, 1 AND 9 INDICATE LEAST AND
-          "                          ".
       01  GENTABLE8 SZ 120 VA "                                       MOST D
-          "ESIRABLE APPLICATIONS, RESPECTIVELY.
-          "                          ".
       01  GENTABLE9 SZ 120 VA "                                    5-PRICES A
-          "RE GIVEN ONLY AS A COMPARATIVE MEASURE OF THE VALUE.
-          "                          ".
       01  GENTABLE10 SZ 120 VA "                                   6-FOLLOWI
-          "NG UNITS ARE NOT SHOWN IN THE TABLE FOR THE SAKE OF
-          "                          ".
       01  GENTABLE11 SZ 120 VA "                                     SIMPLIC
-          "ITY :
-          "                          ".
       01  GENTABLE12 SZ 120 VA "
-          "      MODULUS OF ELASTICITY (100000 PSI)
-          "                          ".
       01  GENTABLE13 SZ 120 VA "
-          "      ELECTRICAL RESISTANCE (.1  MICROOHM-CM)
-          "                          ".
       01  GENTABLE14 SZ 120 VA "
-          "      THERMAL CONDUCTIVITY (10 BTU/HR/SQ.FT/F/FT)
-          "                          ".
       01  GENTABLE15 SZ 120 VA "
-          "      COFF. OF THERMAL EXPANSION (1/DEG.F)
-          "                          ".
       01  FR1 SZ 190 VA "
-          "  TABULATION OF THE RESULT(S)
-          "                          ".
       01  FR2 SZ 190 VA "                                  7-SELECTIONS ARE
-          " BASED ON THE RELATIVE DESIRABILITY OF EACH
-          "                          ".
       01  FR3 SZ 190 VA "                                     MATERIAL WITH
-          "RESPECT TO THE REQUESTED PROPERTIES.
-          "                          ".
       01  FR4 SZ 190 VA "                                  8-DESIRABILITIES
-          " ARE EVALUATED FROM THE NORMALIZED DESIRABI-
-          "                          ".
       01  FR5 SZ 190 VA "                                     LITY MATRIX WH
-          "ICH CORRELATES THE DESIRED AND ACTUAL PROPERTIES
-          "                          ".
       01  FR6 SZ 190 VA "                                    WITH RESPECT T
-          "O THEIR RELATIVE IMPORTANCE.
-          "                          ".
       01  FR7 SZ 190 VA "                                    9-VALUES IN THE
-          "REQUEST COLUMN(S) ARE EXPRESSED IN THE FORM
-          "                          ".
       01  FR8 SZ 190 VA "                                      OF X(Y,Z) WHER
-          "E X IS THE DESIRED VALUE; Y IS THE RELATIVE
-          "                          ".
       01  FR9 SZ 190 VA "                                    IMPORTANCE AND
-          "; Z IS AN INDICATOR OF ACCEPTIBILITY OF LOWER
-          "                          ".
       01  FR0 SZ 190 VA "                                    AND HIGHER VAL
-          "UES DENOTED BY L AND H, RESPECTIVELY.
-          "                          ".
       PROCEDURE DIVISION.
       FLPN. OPEN INPUT CARDF OUTPUT PRINTOUT. MOVE 1 TO N, M. MOVE ZERO
           TO CONT, CTLA, XCTN, DMP.
       R0. READ CARDF AT END GO TO FINISH. IF OPTION = 1 GO TO R1. IF
           OPTION = 2 GO TO R2. IF OPTION = 3 GO TO R3. IF OPTION = 4
           GO TO R4. GO TO R5.
       R1. IF CONT = 0  AND N < 161 MOVE RESTCARD TO MTLOT1 (N) MOVE 1
           TO CONT MOVE CRDNU  TO CRDNO (N) GO TO R0.
           IF N = 161 MOVE CRDNU TO ERR75 WRITE PRINTBLANK FROM ERR7
           AFTER ADVANCING CHANNEL 1 WRITE PRINTBLANK FROM ERR8 AFTER
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     ADVANCING 1 LINES MOVE 1 TO CONT GO TO RD. IF N > 161 MOVE 1
     TO CONT GO TO RD. MOVE "2ND" TO ERR1 MOVE CRONO (N) TO ERR2.
     GO TO E1.
 R2. IF CONT = 1  AND N < 161 MOVE RESTCARD TO MTLDT2 (N) MOVE
     ZERO TO CONT ADD 1 TO N MOVE 1 TO CTLG GO TO RD. IF N > 161
     MOVE ZERO TO CONT ADD 1 TO N GO TO RD.  MOVE "1ST" TO ERR1.
     MOVE CRONO TO ERR2.  MOVE ZERO TO CONT. GO TO E1.
 R3. IF DMP = 1 MOVE CARDFORMAT TO ERR61 WRITE PRINTBLANK FROM
     ERR9 AFTER ADVANCING 1 LINES WRITE PRINTBLANK FROM ERR6 AFTER
     ADVANCING CHANNEL 1. IF DMP = 0 MOVE REST1 TO DMPCRD MOVE 1
     TO DMP. IF CONT = 0 GO TO RD. MOVE "2ND" TO ERR1. MOVE CRONO
     (N) TO ERR2. MOVE ZERO TO CONT. GO TO E1.
 R4. IF DUMMY1 > 9 MOVE CARDFORMAT TO ERR61 WRITE PRINTBLANK FROM
     ERR9 AFTER ADVANCING 1 LINES WRITE PRINTBLANK FROM ERR6 AFTER
     ADVANCING CHANNEL 1. IF DUMMY1 ≤ 9 MOVE REST TO DESVAR (N)
     ADD 1 TO DUMMY1 MOVE 1 TO XCTN. IF DUMMY1 < 10 ADD 1 TO N .
     IF CONT = 0 GO TO RD. MOVE "2ND" TO ERR1. MOVE CRONO (N) TO
     ERR2. MOVE ZERO TO CONT. GO TO E1.
 R5. MOVE CARDFORMAT TO ERR61. WRITE PRINTBLANK FROM ERR5 AFTER
     ADVANCING CHANNEL 1. WRITE PRINTBLANK FROM ERR6 AFTER
     ADVANCING 1 LINES. GO TO RD.
 E1. IF OPTION = 1 MOVE RESTCARD TO MTLDT1 (N), MOVE CRONU TO
     CRONM (N).
 E.  WRITE PRINTBLANK FROM ERR AFTER ADVANCING CHANNEL 1 GO TO RD.
 FINISH. CLOSE CARDF. MOVE ZEROS TO ANSWERS.
         MOVE SPACES TO TITLE16. IF N > 161 MOVE 161 TO N  .
     SUBTRACT 1 FROM N SUBTRACT 1 FROM N.
     IF CTLG = 0 AND XCTN = 1 AND DMP = 1 WRITE PRINTBLANK FROM
     JOB4 AFTER ADVANCING 2 LINES WRITE PRINTBLANK FROM JOB2 AFTER
     ADVANCING 1 LINES GO TO CLOSEFILES1. IF CTLG = 1 AND XCTN = 0
     AND DMP = 0 WRITE PRINTBLANK FROM JOB4 AFTER ADVANCING 2
     LINES WRITE PRINTBLANK FROM JOB3 AFTER ADVANCING 1 LINES GO
     TO CLOSEFILES1. IF CTLG = 1 AND GTABLE ≠ 0 GO TO
     GENERAL-TABLE.
 GT000. IF XCTN = 1 GO TO ORGANIZE-REQUEST.
 GT700. PERFORM ST VARYING K FROM 1 BY 1 UNTIL K = 3. GO TO HD.
 ST. MOVE "*" TO STAR1 (K), STAR2 (K), STAR3 (K), STAR4 (K),
     STAR5 (K), STAR6 (K), STAR7 (K), STAR8 (K), STAR9 (K),
     STAR10 (K), STAR11 (K), STAR12 (K), STAR13 (K), STAR14 (K),
     STAR15 (K), STAR16 (K), STAR17 (K), STAR18 (K), STAR19 (K),
     STAR0 (K).
 HD. MOVE "*" TO STAR8 (3), STAR9 (3), STAR0 (3), STAR10 (3),
     STAR11 (3).
     MOVE "            YIELD STRENGTH                  " TO HDNG (1).
     MOVE "           TENSILE STRENGTH                 " TO HDNG (2).
     MOVE "              ELONGATION                    " TO HDNG (3).
     MOVE "            SHEAR STRENGTH                  " TO HDNG (4).
     MOVE "           BRINNEL HARDNESS                 " TO HDNG (5).
     MOVE "         MODULUS OF ELASTICITY              " TO HDNG (6).
     MOVE "            ENDURANCE LIMIT                 " TO HDNG (7).
     MOVE "              MACHINABILITY                 " TO HDNG (8).
     MOVE "                DENSITY                     " TO HDNG (9).
     MOVE "  COEFFICIENT OF THERMAL EXPANSION          " TO HDNG (10).
     MOVE "         THERMAL CONDUCTIVITY               " TO HDNG (11).
     MOVE "           COMPARATIVE PRICE                " TO HDNG (12).
     MOVE "             MELTING POINT                  " TO HDNG (14).
     MOVE "         ELECTRICAL RESISTANCE              " TO HDNG (15).
     MOVE "        1000 PSI" TO UNIT (1), UNIT (2), UNIT (4),
     UNIT (6), UNIT (7). MOVE "         PERCENT" TO UNIT (3)  MOVE
     "  POUNDS/CU.IN." TO UNIT (9). MOVE "0.000001/DEG.F." TO
     UNIT (10). MOVE "BTU/HR/FT2/F/FT" TO UNIT (11). MOVE "   $/LB
     " X 0.001" TO UNIT (12). MOVE " DEG.FAHRENHEIT" TO UNIT (14).
     MOVE "   MICROOHM-CM." TO UNIT (15). MOVE N TO J2 . WRITE
     PRINTBLANK FROM JOB4 AFTER ADVANCING CHANNEL 1 WRITE
     PRINTBLANK FROM JOB1 AFTER ADVANCING 1 LINES. IF DMP = 0 GO
     TO F . MOVE ZERO TO I.
 LISTING. ADD 1 TO I. IF DMPKEY1 (I) ≠ 1 AND I < 17 GO TO LISTEND.
     IF DMPKEY1 (I) ≠ 1 AND I < 17 GO TO LISTEND  ELSE IF I = 17
     AND DMPKEY1 (I) > 2 GO TO LISTEND. MOVE ZEROS TO J, CTR2.
     MOVE SPACES TO SRTPROP1. MOVE 1 TO CTR1. IF I < 13 GO TO I5.
     IF I = 13 GO TO LISTEND. IF I < 16 GO TO I1. IF I = 16 GO TO
     I3. IF I = 17 GO TO I4. GO TO LISTEND.
 I5. SORT SORTFILE1 ON DESCENDING KEY PVALUE , MATNO1
                   INPUT  PROCEDURE IS SORT1IN
                   OUTPUT PROCEDURE IS SORT1OUT.
 I6. IF XCTN = 0 GO TO LO. IF PNR (I) = 1 MOVE ZEROS TO J GO TO
     DSVRCHECK.
 I0. GO TO LO.
 I1. SUBTRACT 13 FROM I GIVING DUMMY1.
 I2. SORT SORTFILE1 ON DESCENDING KEY PVALUE , MATNO1
                   INPUT PROCEDURE IS SORT2IN
                  OUTPUT PROCEDURE IS SORT1OUT.
 I7. GO TO I6.
 I3. SORT SORTFILE1 ON ASCENDING  KEY SRTNM , MATNO1
                   INPUT PROCEDURE IS SORT3IN
                  OUTPUT PROCEDURE IS SORT3OUT.
 I8. GO TO L1.
 I4. SORT SORTFILE1 ON ASCENDING KEY SRTSCL , MATNO1
                   INPUT PROCEDURE IS SORT4IN
                  OUTPUT PROCEDURE IS SORT4OUT.
 I9. GO TO L2.
 LO. WRITE PRINTBLANK FROM TITLE1  AFTER ADVANCING CHANNEL 1.
     MOVE HDNG (I) TO PROPTTL. WRITE PRINTBLANK FROM TITLE2 AFTER
     ADVANCING 2 LINES. IF I ≠ 5 AND I ≠ 8 AND I ≠ 13 MOVE UNIT
     (I) TO TTLUNIT WRITE PRINTBLANK FROM TITLE3 AFTER ADVANCING
     2 LINES. IF I = 5 MOVE "   AISI B1112 = 100     " TO UNT WRITE
      PRINTBLANK FROM TITLE3 AFTER ADVANCING 2 LINES MOVE "UNITS :
     " " TO UNT1. WRITE PRINTBLANK FROM TITLE4 AFTER ADVANCING
     2 LINES WRITE PRINTBLANK FROM TITLE5 AFTER ADVANCING 1 LINES
     WRITE PRINTBLANK FROM TITLE6 AFTER ADVANCING 1 LINES WRITE
     PRINTBLANK FROM TITLE7 AFTER ADVANCING 1 LINES MOVE " OTHER "
      TO TTLZ WRITE PRINTBLANK FROM TITLE8 AFTER ADVANCING 2 LINES
     WRITE PRINTBLANK FROM TITLE9  AFTER ADVANCING 1 LINES WRITE
     PRINTBLANK FROM TITLE10 AFTER ADVANCING 4 LINES MOVE "********
     "***************************************************" TO
     TTL26 (1), TTL26 (2). WRITE PRINTBLANK FROM TITLE16  AFTER
     ADVANCING 1 LINES. MOVE SPACES TO TTL26 (1), TTL26 (2). MOVE
     ZERO TO K.
 SR.  ADD 1 TO K. MOVE "*" TO ST1 (K), ST2 (K), ST3 (K), ST4 (K),
     ST5 (K), ST6 (K), ST7 (K). IF K < 2 GO TO SR. PERFORM HD THRU
      HX VARYING Z FROM 1 BY 1 UNTIL Z > CTR2. GO TO LISTEND.
 HD. MOVE MNO1 (Z) TO CATNO9 (1),DUMMY2. MOVE PROP (Z) TO PRP99
     (1). MOVE ZEROS TO II. PERFORM HZ VARYING Y FROM 1 BY 1 UNTIL
     Y = 3. GO TO HX.
 HZ. IF DUMMY2 ≠ 0 AND DUMMY2 ≠ SPACES MOVE KCLASS (DUMMY2) TO
     CLS9 (Y) MOVE SUBCLASS (DUMMY2) TO SCL9 (Y) MOVE NAME
     (DUMMY2) TO NA22 MOVE NA221 TO NA251 MOVE NA223 TO NA252 MOVE
      NA25 TO MTLNM9 (Y) MOVE CONDTN (DUMMY2) TO CNDTN9 (Y)
     COMPUTE DUMMY2 FROM CTR2 +Z. IF II = 0 MOVE PROP (DUMMY2) TO
     PRP99 (2). MOVE 1 TO II. MOVE MNO1 (DUMMY2) TO DUMMY1 MOVE
     DUMMY1 TO CATNO9 (2), DUMMY2. IF Z = CTR2 AND CTR1 = 0 MOVE
     ZEROS TO CATNO9 (2), CLS9 (2), SCL9 (2), PRP99 (2)  MOVE
     SPACES TO CNDTN9 (2), MTLNM9 (2).
 HX. WRITE PRINTBLANK FROM TITLE16 AFTER ADVANCING 1 LINES.
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XX. MOVE ZEROS TO DUMMY2.
L1. WRITE PRINTBLANK FROM TITLE11 AFTER ADVANCING CHANNEL 1.
L3. WRITE PRINTBLANK FROM TITLE4 AFTER ADVANCING 2 LINES. WRITE
    PRINTBLANK FROM TITLE5 AFTER ADVANCING 1 LINES WRITE
    PRINTBLANK FROM TITLE6 AFTER ADVANCING 1 LINES MOVE "ALL THE"
     TO TTL7 WRITE PRINTBLANK FROM TITLE8 AFTER ADVANCING 2 LINES
    WRITE PRINTBLANK FROM TITLE9 AFTER ADVANCING 1 LINES  WRITE
    PRINTBLANK FROM TITLE12 AFTER ADVANCING 4 LINES MOVE "********
    ***********************************" TO TTL27 (1), TTL27 (2),
    TTL27 (3). WRITE PRINTBLANK FROM TITLE17 AFTER ADVANCING 1
    LINES. MOVE SPACES TO TITLE17. PERFORM SA VARYING K FROM 1 BY
     1 UNTIL K = 4. GO TO SB.
SA. MOVE "*"  TO ST8 (K), ST9 (K), ST10 (K), ST11 (K), ST12 (K).
SB. IF I = 17 GO TO L4. PERFORM YO THRU YY VARYING Z FROM 1 BY 1
    UNTIL Z > CTR2. GO TO LISTEND.
YO. MOVE MNO1 (Z) TO CATNOB (1), DUMMY2. MOVE SRTNM1 (Z) TO NA22
    MOVE NA221 TO NA251 MOVE NA223 TO NA252 MOVE NA25 TO NTLNMB
    (1). PERFORM YZ VARYING Y FROM 1 BY 1 UNTIL Y = 4. GO TO YX.
YZ. IF  DUMMY2 # 0  AND DUMMY2 < 161 MOVE KCLASS (DUMMY2) TO CLSB
     (Y) MOVE SUBCLASS (DUMMY2) TO SCLB (Y). IF Y = 1 COMPUTE
    DUMMY2 FROM CTR2 + Z. IF Y = 2 COMPUTE DUMMY2 FROM (2*CTR2)+Z
    .    IF (Z< CTR2 - 1 AND Y # 3) OR Y = 1 MOVE MNO1 (DUMMY2) TO
     DUMMY1  MOVE DUMMY1 TO DUMMY2. IF (Y < 3 AND Z < CTR2 - 1)
    OR (Y = 1 AND Z ≥ CTR2 - 1) MOVE NAME (DUMMY2) TO NA22 MOVE
    NA221 TO NA251 MOVE NA223 TO NA252 MOVE NA25 TO NTLNMB (Y+1)
    MOVE DUMMY2 TO CATNOB (Y+1). IF (Z = CTR2 AND CTR1 # 1) OR
    (Z ≥ CTR2 - 1 AND CTR1 = 2) MOVE SPACES TO NTLNMB (3) MOVE
    ZEROS TO CATNOB (3), CLSB (3), SCLB (3).
YX. WRITE PRINTBLANK FROM TITLE17 AFTER ADVANCING 1 LINES.
YY. MOVE ZEROS TO DUMMY2.
L2. WRITE PRINTBLANK FROM TITLE13 AFTER ADVANCING CHANNEL 1.
    MOVE DMPKEY1 (17) TO TTL23. WRITE PRINTBLANK FROM TITLE14
    AFTER ADVANCING 1 LINES. IF SCLASS # 0 MOVE SCLASS TO TTL25
    WRITE PRINTBLANK FROM TITLE15 AFTER ADVANCING 1 LINES.
    GO TO L3.
L4. PERFORM ZO THRU ZY VARYING Z FROM 1 BY 1 UNTIL Z > CTR2.
    GO TO LISTEND.
ZO. MOVE MNO1 (Z) TO CATNOB (1), DUMMY2. MOVE SRTCLS1 (Z) TO CLSB
     (1). MOVE SRTSCL1 (Z) TO SCLB (1). PERFORM ZZ VARYING Y FROM
     1 BY 1 UNTIL Y = 4. GO TO ZX.
ZZ. IF DUMMY2 # 0  AND DUMMY2 < 161 MOVE NAME (DUMMY2) TO NA22
    MOVE NA221 TO NA251 MOVE NA223 TO NA252 MOVE NA25 TO NTLNMB
    (Y) MOVE KCLASS (DUMMY2) TO CLSB (Y). IF Y = 1 COMPUTE DUMMY2
     FROM CTR2 + Z. IF Y = 2 COMPUTE DUMMY2 FROM (2*CTR2)+Z.
    IF Y < 3 AND DUMMY2 < 161 MOVE MNO1 (DUMMY2) TO DUMMY1 MOVE
    DUMMY1 TO DUMMY2, CATNOB (Y+1) MOVE SUBCLASS (DUMMY2) TO SCLB
     (Y+1). IF (Z = CTR2 AND CTR1 # 1) OR (Z ≥ CTR2 - 1 AND
    CTR1 = 2) MOVE SPACES TO NTLNMB (3) MOVE ZEROS TO CATNOB (3),
     CLSB (3), SCLB (3).
ZX. WRITE PRINTBLANK FROM TITLE17 AFTER ADVANCING 1  LINES.
ZY. MOVE ZEROS TO DUMMY2.
LISTEND.  IF I < 17 GO TO LISTING. IF KCTN = 0 GO TO CLOSEFILES1.
F.  MOVE ZERO TO I.
PREPARATION1.  ADD 1 TO I.
001. IF PNR (I) = 0 OR I = 13 GO TO 006. MOVE I TO LX1, CTR1 MOVE
     ZEROS TO J, CTR2 MOVE SPACES TO SRTPROP1. IF I < 13 GO TO I5
     ELSE GO TO T1.
006. IF I < 15 GO TO PREPARATION1. PERFORM COMPUTING-PROPERTIES
    VARYING J FROM 1 BY 1 UNTIL J = N+1.
DESICION. MOVE 1 TO A.
F1. MOVE ZEROS TO MATRICES.  MOVE 1 TO B, BB.
F2. IF B = 6 GO TO F4 ELSE MOVE 1 TO AA.
F3. IF AA = 11 ADD 1 TO B GO TO F2 ELSE IF MATNO (BB) # 0  ADD 1
     TO BB. MOVE STL (A,B,AA) TO MATNO (BB) ADD 1 TO AA GO TO F3.
F4. MOVE 1 TO AA.
F5. IF MATNO (AA) = 0 OR AA = 51 GO TO F12 ELSE MOVE MATNO (AA)
    TO DUMMY1 MOVE 1 TO  AAA.
F6. IF AAA = 6 GO TO F7. MOVE PRPRTY (A,AAA) TO DUMMY2. IF
    DUMMY2 = 0 MOVE 5 TO AAA GO TO F7. IF
    DUMMY2 < 13 MOVE PROPERTY (DUMMY1,DUMMY2) TO SUB ELSE
    SUBTRACT 13 FROM DUMMY2 MOVE PROPERTY (DUMMY1,DUMMY2) TO SUB.
    IF (MAXMIN (A,AAA) = 0 AND SUB > REQVAL (A,AAA)) OR
    (MAXMIN (A,AAA) = 1 AND SUB < REQVAL (A,AAA)) MOVE ZEROS TO
    SUM1 (AA) GO TO F11. IF MAXMIN (A,AAA) = 0 COMPUTE
    VAL1 (AA,AAA) FROM (IMPRTN (A,AAA))*(SUB)/(REQVAL (A,AAA))
    ELSE COMPUTE VAL1 (AA,AAA) FROM (IMPRTN (A,AAA))*(2*REQVAL
    (A,AAA) - SUB)/REQVAL (A,AAA). ADD 1 TO AAA GO TO F6.
F7. IF AAA = 10 GO TO F8 ELSE MOVE PRNO (A,AAA - 5) TO DUMMY2.
    IF DUMMY2 = 0 MOVE 10 TO AAA GO TO F8. IF DUMMY2 > 6 AND < 11
     SUBTRACT 5 FROM DUMMY2 MOVE PROPERTY (DUMMY1,DUMMY2) TO SUB
    ELSE IF DUMMY2 > 10 SUBTRACT 10 FROM DUMMY2 MOVE PROPERTY
    (DUMMY1,DUMMY2) TO SUB ELSE MOVE COMBUSTON (DUMMY1,DUMMY2) TO
     SUB. IF SUB = RTNG (A,AAA - 5) COMPUTE VAL1 (AA,AAA) FROM
    0.5*IMPS (A,AAA - 5). IF SUB > RTNG (A,AAA - 5) COMPUTE VAL1
    (AA,AAA) FROM ((IMPS (A,AAA - 5))*(2*RTNG (A,AAA - 5) - SUB)/
    (2*RTNG (A,AAA - 5)). IF SUB < RTNG (A,AAA - 5) COMPUTE VAL1
    (AA,AAA) FROM  (IMPS (A,AAA - 5))*SUB / (2*RTNG (A,AAA - 5)).
    ADD 1 TO AAA GO TO F7.
F8. IF AAA = 13 GO TO F9. MOVE PNO (A,AAA - 9) TO DUMMY2. IF
    DUMMY2 = 0 GO TO F9. IF (COMPROPY (DUMMY1,DUMMY2) = (0.001*
    RQVL (A,AAA - 9))) COMPUTE VAL1 (AA,AAA) FROM (0.75*IMP (A,
    AAA - 9)) ADD 1 TO AAA GO TO F8. IF (MXMN (A,AAA - 9) = 1)
    COMPUTE VAL1 (AA,AAA) FROM ((3*IMP (A,AAA - 9))/(4*RQVL (A,
    AAA - 9)))*((2*RQVL (A,AAA - 9))-(1000*COMPROPY (DUMMY1,
    DUMMY2))) ELSE COMPUTE VAL1 (AA,AAA) FROM ((3*IMP (A,AAA - 9)
    *1000*COMPROPY (DUMMY1,DUMMY2))/(4*RQVL (A,AAA - 9))). ADD 1
    TO AAA GO TO F8.
F9. MOVE ZEROS TO AAA.
F10. ADD 1 TO AAA. ADD VAL1 (AA,AAA) TO SUM1 (AA).
     IF AAA = 12 GO TO F11 ELSE GO TO F10.
F11. ADD 1 TO AA GO TO F5.
F12. PERFORM SELECTION VARYING B FROM 1 BY 1 UNTIL B = 51.
     MOVE 1 TO AAA.
F13. IF AAA = 6 GO TO F14. ADD IMPRTN (A,AAA), SUM2 (A). ADD 1,
     AAA. GO TO F13.
F14. IF AAA = 10 GO TO F15. SUBTRACT 5 FROM AAA GIVING BBB. ADD
     IMPS (A,BBB), SUM3 (A). ADD 1, AAA. GO TO F14.
F15. IF AAA = 13 GO TO F16. SUBTRACT 9 FROM AAA GIVING BBB. ADD
     IMP (A,BBB), SUM4 (A). ADD 1, AAA. GO TO F15.
F16. MULTIPLY 0.5 BY SUM3 (A) MULTIPLY 0.75 BY SUM4 (A) ADD SUM4
     (A), SUM3 (A), SUM2 (A).
      IF A < M ADD 1 TO A GO TO F1. PERFORM F17 VARYING A FROM 1
     BY 1 UNTIL A = M+1 AFTER B FROM 1 BY 1 UNTIL B =4. GO TO F18.
F17. IF DES (A,B) # 0 AND SUM2 (A) # 0 DIVIDE SUM2 (A) INTO DES
     (A,B).
F18. PERFORM F19 VARYING K FROM 1 BY 1 UNTIL K = 9. GO TO F20.
F19. MOVE "*" TO ST20 (K).
F20. GO TO FINAL-REPORT2.
DSVRCHECK. ADD 1 TO J.
D0. IF RNR (I,J) # 0  MOVE RNR (I,J) TO K ELSE GO TO EX.
     MOVE 1 TO L.
D3. IF L = N + 1 GO TO D2. IF MAXMIN (J,K) = 0 AND
     PROP (L) ≤ REQVAL (J,K) SUBTRACT 1 FROM L ELSE GO TO D7.
D6. PERFORM D5 VARYING II FROM 1 BY 1 UNTIL II = 11. GO TO D2.
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55. ADD ... TO JJ. IF JJ ... < 16 MOVE MN01 (JJ) TO SIL
     (J+K+III).
D7. IF MAXMIN (J,K) = 1 AND PROP (L) < RENVAL (J,K) SUBTRACT 11
     FROM L GO TO D6. ADD 1 TO L GO TO D3.
D2. MOVE ZEROS TO PNR (I), DUMMY1.
EX. IF J < N      GO TO OSVRCHECK ELSE IF LX1 = 1 GO TO 306 ELSE
     GO TO LO.
SELECTION SECTION.
F61. IF SUM1 (B) = 0 GO TO F70.
      IF MATNO (B) = MTL (A,1) OR MTL (A,2) OR MTL (A,3) GO TO F70
     . IF SUM1 (B) > DES (A,1) MOVE DES (A,2) TO DES (A,3) MOVE
     MTL (A,2) TO MTL (A,3) MOVE DES (A,1) TO DES (A,2) MOVE
     MTL (A,1) TO MTL (A,2) MOVE SUM1 (B) TO DES (A,1) MOVE
     MATNO (B) TO MTL (A,1) ELSE IF SUM1 (B) > DES (A,2)  MOVE
     DES (A,2) TO DES (A,3) MOVE MTL (A,2) TO MTL (A,3) MOVE
     SUM1 (B) TO DES (A,2)  MOVE MATNO (B) TO MTL (A,2) ELSE IF
     SUM1 (B) > DES (A,3) MOVE MATNO (B) TO MTL (A,3) MOVE
     SUM1 (B) TO DES (A,3).
F70. EXIT.
COMPUTING-PROPERTIES SECTION.
A3. IF PROPERTY (J,9) ≠ 0 DIVIDE PROPERTY (J,9) INTO PROPERTY
     (J,A) GIVING COMPROPY (J,1) DIVIDE PROPERTY (J,9) INTO
     PROPERTY (J,1) GIVING COMPROPY (J,3). IF PROPERTY (J,12) ≠ 0
     DIVIDE PROPERTY (J,12) INTO COMPROPY (J,1) GIVING COMPROPY
     (J,2) DIVIDE PROPERTY (J,12) INTO COMPROPY (J,3) GIVING
     COMPROPY (J,A).
XIT. EXIT.
SORT1IN SECTION.
P1. ADD 1 TO J. IF J > N GO TO S2.
S1. IF    PROPERTY (J,I) ≠ 0 MOVE PROPERTY (J,I) TO PVALUE MOVE J
     TO MATNO1 ELSE GO TO P1. IF CTR1 = 0 MOVE 1 TO CTR1 ELSE MOVE
      ZERO TO CTR1 ADD 1 TO CTR2. RELEASE SORTREC. GO TO P1.
S2. MOVE ZEROS TO J.
X1. EXIT.
SORT1OUT SECTION.
P2. ADD 1 TO J.
O1. RETURN SORTFILE11 AT END GO TO O2. MOVE PVALUE TO PROP (J).
     MOVE MATNO1 TO MN01 (J). GO TO P2.
O2. MOVE ZEROS TO J.
X2. EXIT.
SORT2IN SECTION.
P3. ADD 1 TO J. IF J > N GO TO S4.
S3. IF PROPERTY (J,DUMMY1) ≠ 0 MOVE PROPERTY (J,DUMMY1) TO PVALUE
     MOVE J TO MATNO1 ELSE GO TO P3. IF CTR1 = 0 MOVE 1 TO CTR1
     ELSE MOVE ZERO TO CTR1 ADD 1 TO CTR2. RELEASE SORTREC. GO TO
     P3.
S4. MOVE ZEROS TO J.
X3. EXIT.
SORT3IN SECTION.
P4. ADD 1 TO J. IF J > N GO TO S6.
S5. IF NAME (J) ≠ SPACES MOVE NAME (J) TO SRTNM MOVE J TO MATNO1
     ELSE GO TO P4. IF CTR1 = 1 ADD 1 TO CTR2. ADD 1 TO CTR1. IF
     CTR1 = 4 MOVE 1 TO CTR1. RELEASE SORTREC. GO TO P4.
S6. MOVE ZEROS TO J.
X4. EXIT.
SORT3OUT SECTION.
P5. ADD 1 TO J.
O3. RETURN SORTFILE11 AT END GO TO O4. MOVE SRTNM TO SRTNM1 (J)
     MOVE  MATNO1 TO MN01 (J) GO TO P5.
O4. MOVE ZEROS TO J.
X5. EXIT.
SORT4IN SECTION.
P6. ADD 1 TO J. IF J > N GO TO S8.
S7. IF KCLASS (J) = DMPKEY1 (17)  MOVE SUBCLASS (J) TO SRTSCL
     MOVE J TO MATNO1 ELSE GO TO P6. IF SCLASS ≠ 0 AND SUBCLASS
     (J) ≠ SCLASS GO TO P6. IF CTR1 = 1 ADD 1 TO CTR2. ADD 1 TO
     CTR1. IF CTR1 = 4 MOVE 1 TO CTR1. RELEASE SORTREC. GO TO P6.
S8. MOVE ZEROS TO J.
X6. EXIT.
SORT4OUT SECTION.
P7. ADD 1 TO J.
O5. RETURN SORTFILE11 AT END GO TO O6. MOVE SRTCLS TO SRTCLS1 (J)
      MOVE SRTSCL TO SRTSCL1 (J) MOVE MATNO1 TO MN01 (J) GO TO P7.
O6. MOVE ZEROS TO J.
X7. EXIT.
ORGANIZE-REQUEST.
      PERFORM OR2 VARYING A FROM 1 BY 1 UNTIL A = M+1 AFTER B FROM
      1 BY 1 UNTIL B = 6. GO TO GT700.
OR2. IF PRPRTY (A,B) ≠ 0 MOVE PRPRTY (A,B) TO DUMMY1 MOVE B TO
     RNR (DUMMY1,A) MOVE 1 TO PNR (DUMMY1).
MOVE TRUNCATION
GENERAL-TABLE. MOVE 1 TO JJJ.
GT. MOVE SPACES TO PRINTBLANK WRITE PRINTBLANK AFTER ADVANCING
     CHANNEL 1 WRITE PRINTBLANK FROM GENTABLE1 AFTER ADVANCING 10
     LINES WRITE PRINTBLANK FROM GENTABLE2 AFTER ADVANCING 3 LINES
     WRITE PRINTBLANK FROM GENTABLE3 AFTER ADVANCING 2 LINES WRITE
      PRINTBLANK FROM GENTABLE4 AFTER ADVANCING 12 LINES WRITE
     PRINTBLANK FROM GENTABLE5 AFTER ADVANCING 1 LINES WRITE
     PRINTBLANK FROM GENTABLE6 AFTER ADVANCING 2 LINES WRITE
     PRINTBLANK FROM GENTABLE61 AFTER ADVANCING 2 LINES WRITE
     PRINTBLANK FROM GENTABLE7 AFTER ADVANCING 2 LINES WRITE
     PRINTBLANK FROM GENTABLE8 AFTER ADVANCING 1 LINES WRITE
     PRINTBLANK FROM GENTABLE9 AFTER ADVANCING 2 LINES WRITE
     PRINTBLANK FROM GENTABLE10 AFTER ADVANCING 2 LINES WRITE
     PRINTBLANK FROM GENTABLE11 AFTER ADVANCING 1 LINES WRITE
     PRINTBLANK FROM GENTABLE12 AFTER ADVANCING 1 LINES WRITE
     PRINTBLANK FROM GENTABLE13 AFTER ADVANCING 1 LINES WRITE
     PRINTBLANK FROM GENTABLE14 AFTER ADVANCING 1 LINES WRITE
     PRINTBLANK FROM GENTABLE15 AFTER ADVANCING 1 LINES MOVE SPACE
      TO PRINTBLANK WRITE PRINTBLANK BEFORE ADVANCING CHANNEL 1.
     MOVE RWLN1 TO ROW-TITLE MOVE SPACES TO PRINTBLANK WRITE
     PRINTBLANK AFTER ADVANCING 4 LINES. PERFORM A1 VARYING K FROM
      1 BY 1 UNTIL K = 9. GO TO G.
A1.  MOVE "*" TO ST20 (K). MOVE RWLN4 TO COLUMN-FIELD (K).
G.  IF JJJ > N GO TO GT600.
G1. MOVE "CATALOG NUMBER" TO ROW-TITLE. PERFORM G2 VARYING J FROM
      1 BY 1 UNTIL J = 9. GO TO G21.
G2. COMPUTE III FROM JJJ + (J - 1). MOVE III TO WA211 MOVE WA21
     TO COLUMN-FIELD (J). IF III > N MOVE SPACES TO COLUMN-FIELD
     (J).
G21. WRITE PRINTBLANK FROM TABLEOUT. PERFORM A1 VARYING K FROM 1
     BY 1 UNTIL K = 9. IF L9 ≠ 0 MOVE RWLN1 TO ROW-TITLE WRITE
     PRINTBLANK FROM TABLEOUT.
G29. MOVE "CLASS" TO ROW-TITLE. PERFORM G3 VARYING J FROM 1 BY 1
     UNTIL J = 9. GO TO G31.
G3. COMPUTE III FROM JJJ + (J - 1). MOVE KCLASS (III) TO WA231
     MOVE WA23 TO COLUMN-FIELD (J). IF III > N MOVE SPACES TO
     COLUMN-FIELD (J).
G31. PERFORM G21 MOVE "SUBCLASS" TO ROW-TITLE PERFORM G4 VARYING
     J FROM 1 BY 1 UNTIL J = 9. GO TO G41.
G4. COMPUTE III FROM JJJ + (J - 1). MOVE SUBCLASS (III) TO WA231
     MOVE WA23 TO COLUMN-FIELD (J). IF III > N MOVE SPACES TO
MOVE TRUNCATION
     COLUMN-FIELD (J).
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G61. PERFORM G21. MOVE "NAME" TO ROW-TITLE. PERFORM G5 VARYING J
     FROM 1 BY 1 UNTIL J = 9. GO TO G51.
G5. COMPUTE III FROM JJJ + (J - 1). MOVE NAME (III) TO WA22. MOVE
     WA221 TO COLUMN-FIELD (J). IF III > N MOVE SPACES TO
     COLUMN-FIELD (J).
G51. WRITE PRINTBLANK FROM TABLEOUT. PERFORM G52 VARYING J FROM
     1 BY 1 UNTIL J = 9. GO TO G53.
G52. COMPUTE III FROM JJJ + (J - 1). MOVE NAME (III) TO WA22 MOVE
     WA221 TO COLUMN-FIELD (J). IF III > N MOVE SPACES TO
     COLUMN-FIELD (J).
G53. MOVE BLNKSL TO ROW-TITLE. PERFORM G21. MOVE "CONDITION" TO
     ROW-TITLE. PERFORM G6 VARYING J FROM 1 BY 1 UNTIL J = 9.
     MOVE 1 TO L9. GO TO G61.
G6. COMPUTE III FROM JJJ + (J - 1). MOVE CONDTN (III) TO
     COLUMN-FIELD (J). IF III > N MOVE SPACE TO COLUMN-FIELD (J).
G61. PERFORM G21. MOVE "S + YIELD (KSI)" TO ROW-TITLE. MOVE 1 TO
     II. MOVE "T +" TO RWLN21.
G70. MOVE ZEROS TO DUMMY1. PERFORM G7 VARYING J FROM 1 BY 1 UNTIL
     J = 9. GO TO G71.
G7. COMPUTE III FROM JJJ + (J - 1). MOVE PROPERTY (III,II) TO
     WA211. MOVE WA21 TO COLUMN-FIELD (J). IF III > N MOVE SPACES
     TO COLUMN-FIELD (J).
G71. WRITE PRINTBLANK FROM TABLEOUT. MOVE RWLN2 TO ROW-TITLE.
     PERFORM G72 VARYING J FROM 1 BY 1 UNTIL J = 9. GO TO G75.
G72. MOVE RWL4A TO COLUMN-FIELD (J).
G75. IF L9 # 0 WRITE PRINTBLANK FROM TABLEOUT.
G8. MOVE "R + TENSILE (KSI)" TO ROW-TITLE. MOVE 2 TO II. MOVE
     "E +" TO RWLN21. PERFORM G70 THRU G75. MOVE "M + SHEAR (KSI)"
      TO ROW-TITLE. MOVE 4 TO II MOVE "G +" TO RWLN21. PERFORM G70
      THRU G75. MOVE "T + FATIGUE" TO ROW-TITLE. MOVE 7 TO II.
     MOVE "H +" TO RWLN21. PERFORM G70 THRU G75. MOVE "  + COMPRES
-    "SIVE (KSI)" TO ROW-TITLE. MOVE 1 TO II.
G81. MOVE ZEROS TO DUMMY1. PERFORM G82 VARYING J FROM 1 BY 1
     UNTIL J = 9. GO TO G81.
G82. COMPUTE III FROM JJJ + (J - 1). MOVE PRAPERTY (III,II) TO
     WA211. MOVE WA21 TO COLUMN-FIELD (J). IF III > N MOVE SPACES
     TO COLUMN-FIELD (J).
G83. PERFORM 421.
G84. MOVE 3 TO II.  MOVE "---" TO RWLN21. MOVE "ELONGATION (%)"
     TO ROW-TITLE. PERFORM G70 THRU G75. MOVE 2 TO II. MOVE "REDUC
-    "TION IN AREA (%)" TO ROW-TITLE. PERFORM G81 THRU G83. MOVE
     5 TO II.  MOVE "---" TO RWLN21. MOVE "BRINNEL HARDNESS      "
      TO ROW-TITLE.  PERFORM G70 THRU G75. MOVE 8 TO II.  MOVE
     "MACHINABILITY            " TO ROW-TITLE. MOVE "---" TO RWLN21.
     PERFORM  G70 THRU G75. MOVE "  + C +" TO RWLN31.    MOVE
     "  +    +INDUSTRIAL ATM." TO ROW-TITLE. MOVE 1 TO II.
G89. MOVE ZEROS TO DUMMY1. PERFORM G90 VARYING J FROM 1 BY 1
     UNTIL J = 9.  GO TO G91.
G90. COMPUTE III FROM JJJ + (J - 1). MOVE CORROSION (III,II) TO
     WA231.  MOVE WA23 TO COLUMN-FIELD (J). IF III > N MOVE SPACES
      TO COLUMN-FIELD (J).
G901. MOVE RWLN4 TO COLUMN-FIELD (J).
G91. WRITE PRINTBLANK FROM TABLEOUT. MOVE RWLN3 TO ROW-TITLE.
     PERFORM G901 VARYING J FROM 1 BY 1 UNTIL J = 9. WRITE
     PRINTBLANK FROM TABLEOUT BEFORE ADVANCING 1 LINES.
G99. MOVE "R + R +" TO RWLN31. MOVE "  + D +MARINE ATM." TO
     ROW-TITLE. MOVE 2 TO II. PERFORM G89 THRU G91. MOVE "A + O +"
      TO RWLN31. MOVE "  + R +SEA WATER" TO ROW-TITLE. MOVE 3 TO
     II. PERFORM G89 THRU G91. MOVE "T + I +" TO RWLN31. MOVE "  +
-    " S + H FL" TO ROW-TITLE. MOVE 4 TO II. PERFORM G89 THRU G91.
     MOVE "I + N +" TO RWLN31.  MOVE "  + O + H2 SO4" TO ROW-TITLE
      MOVE 5 TO II. PERFORM G89 THRU G91. MOVE "N +----" TO RWLN31
     MOVE "  +    + N H3" TO ROW-TITLE. MOVE 5 TO II. PERFORM G89
     THRU G91. MOVE "  + CREEP" TO ROW-TITLE. MOVE "G +" TO RWLN21
     MOVE 1 TO II.
G92. MOVE ZEROS TO DUMMY1. PERFORM G93 VARYING J FROM 1 BY 1
     UNTIL J = 9. GO TO G94.
G93. COMPUTE III FROM JJJ + (J - 1). MOVE PROPERTY (III,II) TO
     WA231. MOVE WA23 TO COLUMN-FIELD (J). IF III > N MOVE SPACES
     TO COLUMN-FIELD (J).
G94. MOVE ZEROS TO DUMMY1. PERFORM G71 THRU G75.
G95. MOVE "  + IMPACT" TO ROW-TITLE. MOVE "S +" TO RWLN21. MOVE
     2 TO II. PERFORM G92 THRU G94. MOVE "  + WEAR" TO ROW-TITLE.
     MOVE "  +" TO RWLN21. MOVE 3 TO II. PERFORM G92 THRU G94.
     MOVE "  + AVAILABILITY" TO ROW-TITLE. MOVE "---" TO RWLN21.
     MOVE 4 TO II. PERFORM G92 THRU G94.  MOVE 12 TO II. MOVE "PRI
-    "CE ( $ / LB. )"  TO   ROW-TITLE. MOVE "---" TO RWLN21.
     PERFORM G70 THRU G75. MOVE 6 TO II. MOVE " MODULUS OF ELASTIC
-    "ITY" TO ROW-TITLE.  MOVE "---" TO RWLN21. PERFORM G70 THRU
     G75. MOVE 9 TO II. MOVE "DENSITY (LB./CU.IN.)" TO ROW-TITLE.
     PERFORM G70 THRU G75. MOVE "MELTING POINT (DEG.F) " TO
     ROW-TITLE. MOVE 1 TO II.
G96. MOVE ZEROS TO DUMMY1. PERFORM G97 VARYING J FROM 1 BY 1
     UNTIL J = 9. GO TO G98.
G97. COMPUTE III FROM JJJ + (J - 1). MOVE PROPERTY (III,II) TO
     WA241.  MOVE WA24 TO COLUMN-FIELD (J). IF III > N MOVE SPACES
     TO COLUMN-FIELD (J).
G98. MOVE "---" TO RWLN21. PERFORM G71.
G9. MOVE "ELECTRICAL RESISTANCE " TO ROW-TITLE. MOVE 2 TO II.
     PERFORM G96 THRU G98. MOVE "THERMAL CONDUCTIVITY  " TO
     ROW-TITLE.  MOVE 11 TO II. PERFORM G70 THRU G75.  MOVE "COEF.
-    "OF THERMAL EXPAN." TO ROW-TITLE. MOVE 10 TO II. MOVE 0 TO L9
     PERFORM G70 THRU G75.
G0. MOVE SPACE TO PRINTBLANK WRITE PRINTBLANK BEFORE ADVANCING
     4 LINES.
G9. ADD 2 TO JJJ GO TO G.
FINAL-REPORTS.
      MOVE SPACES TO PRINTBLANK WRITE PRINTBLANK BEFORE ADVANCING
     CHANNEL 1 WRITE PRINTBLANK FROM FR1 AFTER ADVANCING 10 LINES
     WRITE PRINTBLANK FROM GENTABLE4 AFTER ADVANCING 10 LINES
     WRITE PRINTBLANK FROM GENTABLE5 AFTER ADVANCING 1 LINES WRITE
     PRINTBLANK FROM GENTABLE6 AFTER ADVANCING 2 LINES WRITE
     PRINTBLANK FROM GENTABLE61 AFTER ADVANCING 2 LINES WRITE
     PRINTBLANK FROM GENTABLE7  AFTER ADVANCING 2 LINES WRITE
     PRINTBLANK FROM GENTABLE8  AFTER ADVANCING 1 LINES WRITE
     PRINTBLANK FROM GENTABLE9  AFTER ADVANCING 2 LINES WRITE
     PRINTBLANK FROM GENTABLE10 AFTER ADVANCING 2 LINES WRITE
     PRINTBLANK FROM GENTABLE11 AFTER ADVANCING 1 LINES WRITE
     PRINTBLANK FROM GENTABLE12 AFTER ADVANCING 1 LINES WRITE
     PRINTBLANK FROM GENTABLE13 AFTER ADVANCING 1 LINES WRITE
     PRINTBLANK FROM GENTABLE14 AFTER ADVANCING 1 LINES WRITE
     PRINTBLANK FROM GENTABLE15 AFTER ADVANCING 1 LINES WRITE
     PRINTBLANK FROM FR2 AFTER ADVANCING 2 LINES WRITE PRINTBLANK
     FROM FR3 AFTER ADVANCING 1 LINES WRITE PRINTBLANK FROM FR4
     AFTER ADVANCING 2 LINES WRITE PRINTBLANK FROM FR5 AFTER
     ADVANCING 1 LINES WRITE PRINTBLANK FROM FR6 AFTER ADVANCING 1
     LINES WRITE PRINTBLANK FROM FR7 AFTER ADVANCING 2 LINES WRITE
      PRINTBLANK FROM FR8 AFTER ADVANCING 1 LINES WRITE PRINTBLANK
      FROM FR9 AFTER ADVANCING 1 LINES WRITE PRINTBLANK FROM FR0
     AFTER ADVANCING 1 LINES MOVE SPACES TO PRINTBLANK WRITE
     PRINTBLANK BEFORE ADVANCING CHANNEL 1. MOVE 1 TO A.
FINAL-REPORT. IF A > N+1 GO TO CLOSEFILES1.
F72. MOVE "CHOICE" TO ROW-TITLE MOVE 1 TO AAA. MOVE A TO AA.
F73. MOVE REQUESTNO (AA) TO WA251 MOVE WA26 TO COLUMN-FIELD (AAA)
```

```
18 325          COMPUTE B                                                  MEMORY SIZE 20247
18 33           FROM AAA + 1  MOVE "1ST CHOICE" TO COLUMN-FIELD (B) ADD 1 TO
18 34           B MOVE "2ND CHOICE" TO COLUMN-FIELD (B) ADD 1 TO B MOVE "3RD
18 35    *      "CHOICE" TO COLUMN-FIELD (B). IF M > A + 1 AND AAA = 1 ADD 1
18 36           TO AA ADD A TO AAA GO TO F73.
18 37       F74. IF M ≥ A + 1 MOVE TABLEOUT TO PRINTBLANK ELSE MOVE SPACES
18 38           TO PRINTBLANK MOVE TABLEOUT TO PRBK. WRITE PRINTBLANK BEFORE
MOVE TRUNCATION
18 39           ADVANCING 1 LINES. MOVE RWLN1 TO ROW-TITLE. PERFORM F75
18 40           VARYING K FROM 1 BY 1 UNTIL K = 9. GO TO F76.
18 41       F75. MOVE RWLN4 TO COLUMN-FIELD (K).
18 42       F76. IF M ≥ A + 1 MOVE TABLEOUT TO PRINTBLANK ELSE MOVE SPACES TO
18 43            PRINTBLANK MOVE TABLEOUT TO PRBK. WRITE PRINTBLANK BEFORE
MOVE TRUNCATION
18 44           ADVANCING 1 LINES.  MOVE "DESIRABILITY" TO ROW-TITLE MOVE 1
18 45           TO AAA MOVE 1.00  TO WA271 MOVE A TO B. MOVE WA27 TO
MOVE TRUNCATION
18 46           COLUMN-FIELD (1). COLUMN-FIELD (5). PERFORM F77 VARYING K
18 47           FROM 1 BY 1  UNTIL K = 4. GO TO F78.
18 48       F77. MOVE DES (B,K) TO WA271 MOVE WA27 TO COLUMN-FIELD (K+AAA).
MOVE TRUNCATION
18 49       F78. IF M ≥ A + 1 MOVE 5 TO AAA ADD 1 TO B PERFORM F77 VARYING K
18 50           FROM 1 BY 1 UNTIL K = 4 MOVE TABLEOUT TO PRINTBLANK ELSE
18 51           MOVE TABLEOUT TO PRBK.  WRITE PRINTBLANK BEFORE ADVANCING 1
MOVE TRUNCATION
18 52           LINES. MOVE RWLN1 TO ROW-TITLE. PERFORM F75 VARYING K FROM 1
18 53           BY 1 UNTIL K = 9. IF M ≥  A + 1 MOVE TABLEOUT TO PRINTBLANK
18 54           ELSE MOVE  TABLEOUT TO PRBK. WRITE  PRINTBLANK BEFORE
MOVE TRUNCATION
18 55           ADVANCING 1 LINES. MOVE 1 TO AAA MOVE A TO AA MOVE "CATALOG N
18 56    *      "UMBER" TO ROW-TITLE MOVE SPACES TO COLUMN-FIELD (1).
18 565          COLUMN-FIELD (5) PERFORM F79 VARYING K FROM 1 BY 1 UNTIL
18 57           K = 4 . GO TO F81.
18 58       F79. MOVE NTI (AA,K) TO WA211 MOVE WA21 TO COLUMN-FIELD (AAA+K).
18 59       F81. IF M ≥ A+1 MOVE 5 TO AAA ADD 1 TO AA PERFORM F79 VARYING K
18 60           FROM 1 BY 1 UNTIL K = 4 MOVE TABLEOUT TO PRINTBLANK ELSE MOVE
18 61            TABLEOUT TO PRBK. WRITE PRINTBLANK BEFORE ADVANCING 1 LINES.
MOVE TRUNCATION
18 62            MOVE RWLN1 TO ROW-TITLE. PERFORM F75 VARYING K FROM 1 BY 1
18 63           UNTIL K = 9. IF M ≥ A+1 MOVE TABLEOUT TO PRINTBLANK ELSE
18 64           MOVE TABLEOUT TO PRBK. WRITE PRINTBLANK BEFORE ADVANCING A
MOVE TRUNCATION
18 65           LINES.
19 99       F99. ADD 2 TO A GO TO FINAL-REPORT.
20  1       CLOSEFILES1. COMPUTE AIT FROM (( DATA (1))/60). MOVE "CURRENT TIM
20  11   *      "E OF THE DAY : "  TO AIT1 WRITE PRINTBLANK FROM ACTUAL-TIME
20  12          AFTER ADVANCING CHANNEL 1. COMPUTE AIT FROM ((DATA(2))/60).
20  13          MOVE "ACTUAL PROCESS TIME IS  :" TO AIT1. WRITE PRINTBLANK
20  14          FROM ACTUAL-TIME AFTER ADVANCING 1 LINES. COMPUTE AIT FROM
20  15          ((DATA (3))/60). MOVE "ACTUAL  I / O  TIME IS  :" TO AIT1.
20  16          WRITE PRINTBLANK FROM ACTUAL-TIME AFTER ADVANCING 1 LINES.
20  17          COMPUTE AIT FROM ((64 * DATA (4))/60). MOVE "CURRENT HARDWARE
20  18   -      " TIME IS: " TO AIT1. WRITE PRINTBLANK FROM ACTUAL-TIME AFTER
20  19           ADVANCING 1 LINES. CLOSE PRINTOUT.
20  2           STOP RUN.
20  3       END-OF-JOB........
COMPILE O K . B-5500 02-19-69
PRT SIZE 0392
NO. SEGS. 104
COMPILE TIME 00247 SECS.
TOTAL SEG. SIZE 09744
DISK SIZE 13770
```

APPENDIX E

SAMPLES OF FORMS USED WITH CASEM

Forms used in the transmittal of Materials Information and Requests are shown in Figures 8 through 11. Instructions for the preparation of Materials Data Form and Selection Request Form are in Appendix B and Chapter V, respectively. Delete List and Listing Request Forms are self-explanatory.

☐ ADD ☐ CHANGE DATE:__/__/19__ BY:________________

Units	Entry	Columns	Field
	1	1	Card code
	_	2	Class
	_ _	3-4	Subclass
(ksi)	_ _ _	5-7	Yield strength
(ksi)	_ _ _	8-10	Tensile strength
(Percent)	_ _ _	11-13	Elongation
(ksi)	_ _ _	14-16	Shear strength
	_ _ _	17-19	Brinell hardness
(100 ksi)	_ _ _	20-22	Modulus of elasticity
(ksi)	_ _ _	23-25	Endurance limit
(AISI B1112 : 100)	_ _ _	26-28	Machinability
(0.001 lb/cu in.)	_ _ _	29-31	Density
(0.00001/°F)	_ _ _	32-34	Coefficient of Expansion
(10 BTU/hr/sq ft/°F/ft)	_ _ _	35-37	Thermal conductivity
(¢/lb)	_ _ _	38-40	Comparative price
(°F)	_ _ _ _	44-47	Melting point
(microohm-cm)	_ _ _ _	48-51	Electrical resistance
	_ _ _ _ _ _ _ _ _ _ _ _	52-75	Comments
	_ _ _ _ _ _ _ _ _ _ _ _		
	_ _ _ _ _	76-80	Card number
	2	1	Card code
	_ _ _ _ _ _ _ _ _ _ _	2-26	Name
	_ _ _		
	_ _ _ _ _ _ _ _ _ _ _	27-37	Condition
	_ _ _ _ _ _ _ _ _ _ _		
Corrosion Ratings	_	38	Industrial atmosphere
	_	39	Marine atmosphere
	_	40	Sea water
	_	41	Hydrochloric acid
	_	42	Sulphuric acid
	_	43	Ammonia
(ksi)	_ _	44-45	Compressive strength
(Percent)	_ _	46-47	Reduction in area
Other Ratings	_	48	Creep
	_	49	Impact
	_	50	Wear
	_	51	Availability
	_ _ _ _ _ _ _ _ _ _ _ _	52-75	Comments
	_ _ _ _ _ _ _ _ _ _ _ _		
	_ _ _ _ _	76-80	Card number

Figure 8. Materials Data Form

DELETE LIST

TO THE DATA PROCESSING CENTER:

The following materials data cards should be deleted from CASEM Catalog Card File:

ITEM	CLASS	SUBCLASS	NAME	CARD NO.
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				

By: ______________________

Dept.: ______________________

Date: ______________________

Figure 9. Delete List

CASEM LISTING REQUEST FORM

Write "1" into the blank for the listing requested.

Column		Property Listing
1	3	Code
2	__	Yield strength
3	__	Tensile strength
4	__	Elongation
5	__	Shear strength
6	__	Brinell hardness
7	__	Modulus of elasticity
8	__	Endurance limit
9	__	Machinability
10	__	Density
11	__	Coefficient of thermal expansion
12	__	Thermal conductivity
13	__	Comparative price
15	__	Melting point
16	__	Electrical resistance
17	__	Alphabetical listing
18	__	Class listing (fill in the class number)
19-20	__ __	Subclass listing (class must be indicated above)
21	__	Complete catalog listing

By: ____________________________

Dept.: ____________________________

Date: __/ __/ 19__

Figure 10. Listing Request Form

CASEM

SELECTION REQUEST FORM

By: ____________

Dept.: ____________

Date: ____________

	Number	Importance	Optimization	Optimum Value	Card Columns
Card Code	4				01
PRIMARY PROPERTIES	__ __	__	__	__ __ __ __	02-09
	__ __	__	__	__ __ __ __	10-17
	__ __	__	__	__ __ __ __	18-25
	__ __	__	__	__ __ __ __	26-33
	__ __	__	__	__ __ __ __	34-41
RATINGS	__ __	__		__ __	42-46
	__ __	__		__ __	47-51
	__ __	__		__ __	52-56
	__ __	__		__ __	57-61
COMPOSITE PROPERTIES	__	__	__	__ __ __	62-67
	__	__	__	__ __ __	68-73
	__	__	__	__ __ __	74-79
Request	__				80

Figure 11. Selection Request Form

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