6 3 3-2

DEVELOPMENT AND IMPLEMENTATION OF A MATERIALS INFORMATION PROCESSING SYSTEM

FOREWORD

This report was prepared by the Belfour Engineering Company under Contract No. AF33(616)-8046. This contract was initiated under Project 1(8-7381), "Materials Applications", Task No. 738103 "Data Collection and Correlation". The work was administered under the direction of the Applications Laboratory, Directorate of Materials and Processes, Deputy for Technology, Aeronautical Systems Division, with Lt. D. M. Ingels acting as project engineer.

This report summarizes work done from February 1961 through April of 1962.

ABSTRACT

A program is described for acquisition, storage, analysis and dissemination of materials information. A specific and representative portion of the Materials Information System is used as a model and discussed in detail. The System is designed to store individual test data and associated descriptive information. It therefore provides the capability for data analysis based on complex interactions, graphic or tabular display of data, and more conventional bibliographic output.

This technical documentary report has been reviewed and is approved.

D. A. SHINN
Chief, Materials Information Branch
Application Laboratory
Directorate of Materials and Processes

TABLE OF CONTENTS

PAGE

1.0 INTRODUCTION

Making information available in specific technical subject areas is not a new endeavor, even though a cursory look at current literature might give that impression. The literature is now being flooded with new publications of information about information. These come under many different headings, some of which are: "Library Science", "Documentation", "Information Storage & Retrieval", or "Information Processing". There may be some differences between the subjects mentioned above; however, they seem to be largely a matter of viewpoint and degree. Much of the available literature on this subject seems to be concerned with the difference in concepts that separates these designations. Rather than add to this already overworked subject, this report will describe one means of providing materials information. This discussion will use as a model, the Materials Information Processing System developed under Contract No. AF33(616)-7238, Progress Reports 1 through 9. For convenience, we refer to it as an "Information Processing System". It can provide materials information in any or all of the following forms:

Pertinent References
Selective Data
Evaluated or Analyzed Data

In order to make all the above forms of information available, the System is set up to store data point co-ordinates as well as other pertinent information contained in technical documents.

2.0 SUMMARY

To the extent that reports of materials properties and associated variables are given in "formal" language, the storage, processing, and retrieval of this information can be described by a set of procedures and rules. Once these rules are developed, many of the storage, processing, and retrieval procedures can be expedited by high-speed machine processes.

The program described in the following pages could provide a system (including procedures and hardware) for storing, retrieving, processing, evaluating, and displaying mechanical properties information. The current Mechanical Properties Information Processing System, developed under Contract No. AF33(616)-7238, Progress Reports 1 through 9, will serve as a model for the recommendations for a more general "Materials Information System". The active System now contains, in its file, more than 2,000,000 "units" of information. Each unit of information can provide an address to a reference or mechanical property while also serving as a modifier for definition of variables which affect the data.

The data processing concepts and procedures on which this active System is based, result in a dynamic capability which can be adjusted periodically to satisfy current requirements. Elements of the input procedures and form in which information is stored, result in complete freedom of choice of commercially available data processing equipment, as dictated by activity and economic considerations.

3.0 DISCUSSION

3.1 Some Basic Principles

The goals of this program should provide information for current and future application, not just a data processing system operating in an economic and social vacuum.

To justify the expenditure of both time and money on this program, it should be established: first—that the results of the program can provide useful information which is not already available; second—that this can be achieved economically. This discussion will demonstrate that both conditions stated above are not only possible, but to a large extent, have been demonstrated in practice in the work currently being accomplished under Contract AF33(616)-7238, Progress Reports 1 through 9.

To evaluate the variety of methods for operation of a Materials Information Processing System, it will be helpful to consider some of the approaches which have governed both successful and unsuccessful efforts in solving this and similar problems. Much of this has already been reported in the past. Therefore, the following considerations are important:

In this relatively new field of Information Processing, the successful programs are invariably associated with relatively simple and understandable goals, procedures, and hardware. They are usually identified as semi-automatic systems incorporating an abundance of man-machine relationships. The inherent intelligence of man is utilized in conjunction with, or to augment, the capabilities of machines. Machines are used only to perform the "formal" tasks at high rates of speed. By "formal" we mean operations which can be described by a set of rigid, unambiguous rules.[1]

Paradoxically, the successful information storage and retrieval programs seem to cost significantly less in providing useful results than the unsuccessful development programs which are usually phenomenal in cost and provide little or no useful output. Some of the reasons for this are obvious: the unsuccessful programs almost always emphasize development of ultra-complex concepts (often mislabeled "sophisticated")and equipment (the means rather than the end). The interaction of these two factors obviously skyrockets costs. Unfortunately, this usually results in attempted solutions which veer increasingly farther from good common sense. The original problems and goals are lost in the mistaken belief that what is required is a more complex and costly development. Failure to perform is usually blamed on inadequate technology and hardware. Failure is rarely blamed on inadequate thinking. Progress and complexity are not necessarily synonymous.

3.2 General Approach

The recommended program has been developed by use of relatively simple and basic procedures. First, based on our experience in the field of information processing, it is necessary to identify and describe the major work areas involved in the operation of an information processing program. Second, it is necessary to describe the general principles, methods, and alternatives which will be evaluated and incorporated in achieving this program.

1. Taube, "Computers and Common Sense". Columbia University Press, 1961.

In many successfully operating information systems, key technical personnel have usually been involved in the development and application of many basic concepts for a considerable length of time; therefore, many of the solutions described below are in the category analogous to routine production development and control. This is an important aspect of any proposed system operation. In our own experience in development and operation of many diverse information processing systems, significant portions of information system development programs are now routine.

In order to simplify the identification of this particular System in the following discussion, we will abbreviate Materials Information Processing System and in the future refer to it as MIPS. The following listing identifies the categories of work desirable in the initial evaluation and development phase.

Identification of Major Work Areas

Materials Selection
Mechanical Properties Selection
Associated Information Selection
System Language and Processing Machines
Procedures and Formats
Inventories and Controls
Source Document Acquisition
Data Analysis and Presentation
System Output

3.3 Detailed Approach

The following is a detailed discussion of the considerations involved in each work area listed above, and our recommendations for accomplishing the work involved in each specific area. Resolution of the problems associated with these items, described in detail below, results in an operational system. With establishment of an operational system other considerations are required. These will be discussed in Section 3.3.3.

1. Materials Selection

Current interest, as well as discussion with ASD personnel, indicates that the first consideration should be given to "relatively new and interesting metals". Since this is a relative statement and does not serve to identify any particular type of metal, we approached this problem through two basic assumptions: first, that by "new" it is intended that a metal be developed beyond the basic research stage and to a degree reasonably advanced for at least limited preliminary application; second, that by "interesting" we can assume that the current Abstract of Active Contracts of Materials Central (1 August 1961) lists, within reasonable limits, metals which are of current interest to both the Government and defense industries.

In general these metals fall into a class which can be described as High-Strength, Corrosion and Heat Resistant Metals. Since design problems involving corrosion and heat resistance are often solved with materials other than metals, we propose that the materials classification mentioned above be broadened to the more general one of High-Strength, Corrosion and Heat Resistant Materials. The earliest work, therefore, should include the development and initiation of procedures for the system to include information for both Metals and Reinforced Plastic Materials in the high-strength, corrosion and heat resistant categories.

It will be further demonstrated that the development of data processing procedures for handling the more <u>specific</u> classification, "Corrosion and Heat Resistant Metals and Plastics", described above will also be suitable for handling the more <u>general</u> classification of "Metals" and "Plastics". This is an important point; since we should not try to determine, at this early stage, which information is "interesting" or useful. Unsolicited interrogation of any system for specific information concerns subject matter which is ipso-facto "interesting" or necessary. In this context, we should equate "interest", not with "curiosity", but with "concern".

Storage of information pertaining to relatively common, commercially available materials is strongly recommended. The availability of large quantities of information, suitable for reliability evaluation, is in itself a valid reason for industry to consider commercially available materials. If we refrain from imposing arbitrary limitations on data storage, the processing system will have an inherent capability to help solve a wide variety of application problems.

2. Mechanical Properties Selection

The particular properties for consideration and inclusion in this program should all be under the general heading of Mechanical Properties of Materials. These will be identified and divided into main categories and detailed sub-divisions, also identified. Typical categories and properties which should be considered for storage are listed below:

Static Properties

Ultimate Strength

    Tension
    Compression
    Shear
        Horizontal
        Vertical
        Torsional
        Panel
        Interlaminar (for plastics)
        Edgewise (for plastics)
    Bearing
    Flexure (modulus of rupture)

Yield Strength (@ .2% offset)

    Tension
    Compression
    Flexure
    Bearing

Proportional Limit

    Initial and Secondary (for plastics)
    Tension
    Compression
    Flexure

Modulus of Elasticity

>Initial and Secondary (for plastics)
>Tension
>Compression
>Flexure

Tangent Modulus (where applicable)

Hardness

Elongation at Failure

Impact

Poisson Ratio

Dynamic Properties

>Fatigue

>>(Axial, Rotary, Torsion, Combined)
>>Conventional S-N Test
>>Rerun S-N Test
>>Damage Test
>>Sequential Loading Test
>>Random Loading Test
>>Prot Test

>Damping Constants

Creep Properties

>Time-Deformation

>Stress-Rupture

The exact mechanical properties to be stored in the MIPS System should be determined by the system management, based on present and probable requirements. The properties listed above are intended as typical of those which can be stored, processed, and retrieved in a mechanized data processing system. The system storage will, of course, be subjective, in that only those properties which are reported can be stored as basic information.

Information, such as weight/strength ratios are not to be included as basic mechanical properties. These will be considered as "derived information". Provision for computing and supplying derived information and other comparatively determined properties will be discussed below.

3. Associated Information Selection

Under this category we include all of the associated information required to modify each recorded mechanical property and contribute to its definition. It will be helpful here to consider the definition of "information" as—that which provides the basis for intelligent action.

Before the requirement existed for ultra-efficient and high deformation design, it was sufficient, for most applications, to state in general that commercial steel had an ultimate tensile strength of 35,000 psi. The working stress was a small percentage of ultimate or yield and typical handbook values (containing a minimum of definitive information) sufficed.

In order to achieve the levels of reliability required by current, efficient design concepts, each of the mechanical properties must be associated with additional descriptive details. This is necessary in order that the conditions under which the noted property was obtained can be reproduced or evaluated as they may affect the observed quantitative magnitude of the property.

The above discussion refers to the area which, for practical purposes, we will consider definable and controllable variables. Another area of variability can be observed when all of the so-called controllable and definable quantities are held constant. This remaining variability in test results, after all the "usual" controls are applied, will be labeled inherent variability. This concept will always be subject to state-of-the-art and economic considerations. However, the category of inherent variability exists and does contribute to structural failure. The recommended System will provide a means for evaluating both types of variability discussed above.

The type of "associated information" required to provide a relatively complete definition of the mechanical properties to be stored in the System, falls into two categories: formal and informal. Formal information is that portion of a mechanical properties determination which can be described by a rigid set of rules (such as MIL or ASTM specifications) or relatively unambiguous quantitative expressions such as "load application rate = 1000 lbs/min". There is little danger that such a statement will be misinterpreted.

Informal information are those portions of any mechanical properties determination which are usually given in common language (words, phrases, etc.) and require interpretation. The author's ability to identify and convey these thoughts must be coupled with the ability of some talented, trained human being, engaged in the activity of information processing, in order to convert this informal information to a processable form for inclusion in the System. This type of information cannot be ignored any more than the "discussion" or "comments" section of a test report can be ignored. However, it is too much to expect that this type of information can always be reported or stored in an exact one-to-one relationship with the original facts.

Encoding and extracting procedures should be such that the degree of ambiguity will be indicated in converting informal information to system language. This is exemplified in present coding systems which provide indications for three levels of relationship between coded information and reported information:

1. Item is complete and unambiguous.

2. Item is unambiguous; however, more information is available in source document.

3. Item is not adequately described, reference to source document is required.

These indications of degree of relationship refer to information converted to system language and its relationship to information contained in the source document. Obviously, the responsibility for including and describing all pertinent facts in any report must be assumed by the author. It is impractical to attempt the development of a Materials Information Processing System of this type without including indications of "degree of relationship" as auxiliary modifiers.

The major categories and typical sub-divisions for associated information proposed for complete definition of metals and plastics mechanical properties are as follows:

1. Source of information
2. Formulation of basic stock
3. Manufacturing processes involved in preparing test lots and specimens
4. Specimen configuration and geometry
5. Pre-test environmental conditions
6. Test environmental conditions
7. Test methods, procedures, and equipment
8. Test loads (including load application rates)
9. Test results
10. Post test measurements and failure descriptions

Examples of how the inclusion of this type of information is achieved in a fixed-format/open-coding system have been submitted under Contract AF33(616)-7238, Progress Reports 1 through 9. For new developments we recommend a more detailed breakdown of the "associated information" category, particularly in the descriptive information referring to processing variables.

4. System Language and Processing Machines

The Unit Record is the basic concept behind the choice of procedures, equipment, and overall data processing techniques for this System. The building blocks of the recommended System are composed of individual specimen test results, including all the most obvious associated descriptive information. All of the information pertaining to each mechanical property determination (usually the result of a test) forms a "unit record" and is stored as a complete retrievable entity. Each category of information (field) is addressable and can be individually processed or retrieved. Complete flexibility is provided for merging these unit records by any of the subdivisions within any of the categories of information which are listed above.

Data which will be contained in the System storage will have been extracted from common reports. Each data point is composed of as many units or fields of information (of the type listed above) as are included and described in the source document. Much of the associated information will be common to all unit records from one source document (for example, the identification of the source document itself). Usually more than one set of conditions are established for a test program. This results in sets of unit records having common information in some categories (material, formulation, processes, environment, test procedure, etc) but not others.

The ability to identify, retrieve, and organize information originating from a common source document at a high rate of speed is a worthwhile goal in itself. However, the really exciting potential offered by the unit record concept is the

·ability to identify, merge, retrieve, or process <u>any</u> common information, no matter what its source, while maintaining the identity of each source document and its specific information contribution.

All quantitative information in both the Properties and Associated Information categories will be stored in their numerical form incorporating a floating decimal system for efficient use of the storage media. All quantitative information will be addressable and definable as to sign and units and scales of measurement so that the System provides complete freedom for any desired calculations involving the stored numerical information.

Input of numerical information will in most cases involve conversion of mixed units and scales to common ones for ease of storage and processing. For instance, hardness of metals can be converted to a Diamond Pyramid Scale for storage, since this one scale can accomodate the wide range of metal hardness with good intermediate definition. However, if conversion is required, the particular units and measuring technique reported in the source document will be identified along with the converted hardness value. This type of conversion identification is desirable throughout the System in order that we may process data using common measuring scales and units without losing the significance of the original measuring technique.

Rounding-off of numerical information will be r ···ired for practical ease of storage and processing. In no case will the accuracy   ·umerical information be affected by greater than ± 1.0% by the rounding-off techniques.

All pertinent information other than numeric will be encoded through the establishment of various alpha-numeric code dictionaries. These will be developed along with the required modifiers by "blocking" of code numbers from general to specific. Specific codes need not be developed or assigned until a requirement is indicated within a source document. In other words, specific codes need not be identified or assigned before a need is encountered.

This technique minimizes code complexity and unnecessary development expenditures. Some information processing development programs have recently expended most of their funds on the development of code dictionaries which were voluminous, inefficient, and mostly useless, simply due to trying to out-guess conditions before they were encountered.

Storage and processing of information in numerical form is relatively simple and economical. The apparent complexities are fewer and less severe than those associated with alphabetic processing. Experienced personnel quickly become accustomed to the new "language". Intermediate translation from system to common language is often done by inspection. However, full scale translation is accomplished by more formal machine de-coding techniques.

The recommended unit-record, numeric storage approach for the development of the System can be accomodated by a wide variety of machines. There is no truly optimum system—many different systems can work. The specific hardware is really a secondary consideration—since experienced personnel can operate the proposed System on many of the commercially available machines. The important thing is, that the hardware costs and complexities are compatible with the current activity

requirements of the System, and that provisions are available for improvement in the categories of storage capacity and speed of processing, retrieval, and output.

Our present experience indicates that punched cards, utilizing an open ended, fixed-format/open code data input technique will serve initially as efficient and practical storage and processing media for the System. As further requirements demand, these can be converted to magnetic tape to alleviate certain storage problems. Processing can be accomplished in either form through readily available card/tape converters, depending on the particular problem. The present Fatigue Data card file (Contract AF33(616)-7238, Progress Reports 1 through 9) is being converted to magnetic tape to facilitate inactive storage and transportation of the file. Card processing is still considered most practical for current processing problems.

Complete storage of the System in the "memory" of a full scale random access computer is an impractical consideration for the next year or two. However, the long range implications of such a system potential should certainly be investigated since an efficiently functioning System will result in "self generated traffic", stimulating its own use and growth.

5. Procedures and Formats

In order for the proposed System to function it is necessary that formal procedures be developed for:

Extracting and encoding from source documents.
(common language to system language)

Information Input and Storage
(system language to machine language)

Updating Inventories

Processing and Retrieval
(machine language to system language)

Analysis and Output
(system language to common language)

The open-end/fixed-format concept, incorporated in past work of this type (Contracts AF33(616)-7238, Progress Reports 1 through 9; AF33(616)-2840, final unpublished report; AF33(616)-3301, WADD-TR 58-461) provides the simplest, most practical basis for developing relatively rigid rules and procedures for accomplishing the operations listed above. It is a proven concept for storing, processing, and transmitting complex information and has been used efficiently as the basis for International Synoptic Weather Code for more than forty years.

The fixed-format system proposed for this program will not be limited by the necessity to outguess future problems, since each format is open-ended. New information can always be added without adversely affecting what is already in the

System. All that is required is that whatever is fixed, is fixed! Ambiguity is therefore minimized and development of procedures is relatively routine for: extracting information, automatic duplication of common information, identification, and definition of information, etc. Complete control of all information at all times is _mandatory_ and must be afforded with relative ease. The recommended Information Processing approach provides the means of achieving the required control.

As we approach complete and rigorous definition of formats and procedures, we minimize the possibility of inadequate system capability with respect to processing current and familiar information. However, we must recognize the probability that in the future, certain deficiencies will appear in the system's ability to process information involving newly developed materials and concepts. We, therefore, suggest that the established procedures and formats be modified in two ways: first, future requirements for addition of information can be handled by the fact that the formats, procedures, and codes are open-ended, as described above; second, the established formats, procedures, and codes should be reviewed periodically (perhaps annually) and modifications made where indicated. The data processing system itself can be used to indicate certain types of deficiencies, such as frequency of utilization of each field of information, etc. Automatic data processing systems can be notorious in continuing to carry an inefficient operation, usually "because it is too much work to change the system".

6. Inventories and Controls

Experience with many high-volume information processing systems has demonstrated that certain control inventories are essential for intelligent and efficient management of the system. They reduce the necessity for most inefficient machine processing and also provide an extremely efficient means of estimating the potential yield or response to an interrogation of the system. Inventories can provide this, and additional, useful information by inspection, before any buttons are pushed. Some of the thought behind our discussion of man-machine relationships and information processing system efficiency may be illustrated by the above consideration.

Control inventories also provide indications of the types of source documents which should be scheduled for encoding in order to provide balanced information coverage. They have also, in the past, provided indications of non-existent or inadequately covered areas of materials and/or process development. These inventories have been valuable tools for helping to organize procurement programs as well as indicating the minimum requirements for subject matter coverage within a development program.

Inventories are prepared by simply listing the quantity of data stored under various specific or interacting categories of subject heading. These interacting categories must be chosen by individuals having experience and knowledge of the subject matter or vast quantities of pure nonsense can result. This is not uncommon and has been observed with alarming frequency, when work of this type is left to the judgement of pure data processing personnel. It is obvious from this that the System can be completely inventoried under a list of headings pertaining to _production_ or _fabrication processes_. The flexibility of the _unit record_ concept is again indicated.

Erroneous storage and faulty procedures associated with high-speed processing systems provide a continuing problem area, since large volumes of information are involved and they are a few steps removed from their original source. In the final analysis, the responsibility for valid output can neither be assigned to nor assumed by a machine. Intelligent, human evaluation of the information at various stages in processing and output, is mandatory for both economy and output validity. We, as individuals, not the system, must assume the final responsibility for valid and pertinent information output.

It is obvious that the closer to the source that errors can be detected, the less wasted processing will result. Therefore, informed evaluation of the information must be conducted by experienced personnel at specific stages of processing.

The development and implementation of operating controls should be treated as a primary consideration. These will include such areas as:

1. The evaluation of source documents for duplicate and/or summary data.

2. Data extraction, for accuracy and valid interpretation.

3. Data input verification.

4. Preliminary print-out and display before merging. This is the last point at which the combined data from one source document are together before merging with the remainder of the file.

5. Duplicate data file reproduction and verification.

6. Inventory crossfoot checks.

7. Search output check against inventory for total data count by subject matter.

8. Verification of all conventional search output against available summary data (by subject).

As stated above, all check points and formal controls should include visual inspection of information at various processing stages, in order to guarantee that the information being processed and disseminated is reasonable and rational. The "unit record" storage concept lends itself extremely well to efficient checking and control.

7. Source Document Acquisition

We are often asked whether we have "all" the data on a particular subject, or "how much" of the data we have stored. Obviously, no system can claim it contains "all" the information on any subject. For the same reasons no intelligent answer exists to the question of "how much" of the data is stored. No reasonable method exists for determining the available quantities of technical information, nor is it really necessary that we know the totals.

The only practical goal in building up the file, is to attempt to acquire and store "a lot" of mechanical properties data and associated information about as many different, useful materials as is economically possible. Personal contact

and coordination will be required in order to maintain "adequacy" of the file. The method of choosing specific materials was discussed above. However, an overriding consideration exists, tending to make the choice of specific materials for storage a subjective rather than an objective function. The consideration is simply that current technical reports and other current source documents can logically be assumed to contain information of current interest.

Acquisition of potentially useful source documents involves consideration of two separate and distinct types of information media: published and unpublished information. Both must be considered in order to best satisfy the requirements of this development. A discussion and approach to obtaining each type of information is given below.

It will be necessary that system personnel develop and maintain a backlog of information source documents. Pertinent published documents may be identified through the use of ASTIA (TAB and Bibliography service), DOD, Plastec, DMIC, Western Reserve, Bureau of Standards, Abstract of Active Contracts at Materials Central, Office of Naval Research, Forest Products Lab., ANC-5 Committee, etc. Active personal contact with the Aero-Space Industry and its trade journals also highlights potentially useful information.

For the purpose of the Materials Information System, we believe document acquisition to be a problem of control. The services mentioned above collect and announce many technical publications, and most of them are continually improving their coverage. Until the operating information system assimilates much of the data in existing technical literature, and is functioning on a current basis, acquisition can easily exceed system operation speed. System input speed is, of course, simply dependant on the overall rate of effort considered practical.

There are at least two additional categories of information (both unpublished) which must be considered as potentially useful sources. Obtaining these may require Government assistance.

The first is the large volume of unpublished data, generated by air-frame manufacturers, in the development and evaluation of structural components and pro-cesses. These are usually associated with a Government sponsored development program. The general availability of this information and subject matter coverage can be ascertained by the Government and, if desired, procurement can be initiated for the collection and organization of this information. This recommendation does not depart much from what is presently being done by ASD, except that the proposed inventories of stored information may be helpful in evaluating the requirement for each part-icular type of information.

The second source of unpublished materials properties, potentially useful to the System, is the large volume of quality control data routinely gathered during the production of commercially available structural materials. This type of infor-mation is ideally suited for statistical evaluation of properties variations within common material lots and also for indications of lot-to-lot variations.

We believe that materials producers would, in general, be interested in making this data available to a reliable dissemination system. This subject has been discussed with many of the foremost producers of reinforced plastic materials, who generally are agreeable to an exchange of information. They could provide large

volumes of production quality control data in exchange for summaries of equivalent typical information. Government assistance may be helpful in obtaining such information.

To provide a balanced file of materials information, we should consider, as part of the overall system, the entire category of published documents which describe and summarize materials, processes, and properties. These are typified by documents such as MIL-HDBK-5, ANC-18, handbooks in general, DMIC Reports, Plastec Reports, Air Weapons Materials Application Handbook by Syracuse University Research Institute, special state-of-the-art reports, current trade journals, etc.

These documents do not necessarily contain individual test results; however, they do in various ways present summaries and evaluations of information in general, pre-determined subject areas. Often, large portions of the data evaluated in these handbooks are already stored in the processing system. Since these documents are general and usually present trends rather than individual test results, they are not suitable for unit record storage. The information contained in these summaries and handbooks can be stored in a supplementary system which processes, as a unit, an entire trend or summary tabulation. Aperture Cards offer a potential medium for providing overall system compatibility. Storage and retrieval can be accomplished using the same encoding and processing principles incorporated in the primary System. In other words, all fields of information can be identical to the main System. The departure takes place at the point of listing individual test results. In the case of Summary Information, the test result field would contain the entire trend or tabulation shown in the reference.

The System should be able to provide interrogators with the maximum amount of useful information available, in answer to their questions. Summary Information helps to round-out the presentation, and in some cases adds authenticity to the output.

8.   Data Analysis and Presentation

In many cases the results of an information search can be presented in simple graphical and tabular form. These usually include the necessary identification and labeling of pertinent subject matter and descriptive information. Recommendations of the ANC-5 Committee are helpful in establishing the minimum requirements for definition of associated information. Pertinent information which was not available or not adequately defined in a source document should be identified as such.

It will often be desirable to perform various types of statistical analyses of the information stored in the System: for the purpose of providing "evaluated" results as answers to specific questions initiated externally; also for internally generated materials properties evaluation programs. The System itself helps to provide reasonable quantities of data required by the contemplated statistical determinations.

To provide the analytical flexibility and potential which will prove to be useful in conjunction with the overall operation of the System, we suggest development of the detailed procedures and/or computer programs (where applicable) for at least the following determinations:

1. Computation of correlation coefficients for quantitative variables vs properties.

2. Determination of most probable statistical population from which observed property scatter was sampled.

3. Definition of central tendencies and expected variation based on observed data sample.

4. Determination of probability that a given property will exceed a specified value.

5. Determination of probability that a given property will fall between specified values.

6. Determination of probability that observed properties were sampled from the same or different statistical populations.

Derived information, such as ratios of comparatively determined properties, are relatively simple computations which can be performed as indicated during the routine data processing procedures.

9. System Output

This phase of the work requires two separate (but related) considerations: the first, routine information dissemination lends itself to an objective solution; the second, providing answers to specific questions is a relatively subjective problem requiring a different approach to the use of the System.

In the first case, routine information dissemination, we suggest that personnel of Materials Central make recommendations for a suitable subject of current interest for each scheduled report. The subject may be derived from any category of information stored in the system; specific material, properties, processes, environmental conditions, etc. The scope of coverage will depend on the amount and depth of available information. We must assume that a "reasonable" quantity of data are stored in the System before routine dissemination is instituted.

A bi-monthly schedule is suggested for routine dissemination of data sheets to be generated by the System. Experience has shown that a mailing list containing up to 300 names and addresses may be developed with the assistance of ASD personnel for routine dissemination of data sheets. Further distribution can be accomplished by ASTIA.

The data sheets, themselves, will present tabular and graphical displays of relationships between mechanical properties of materials of current interest and other stored or derived factors having current and practical application. Certain data sheets can be visualized which deal entirely with derived information such as weight/strength relationships or percentage of room temperature property retention at elevated temperatures, etc.

Data evaluation should be performed wherever required and justified by the volume and type of stored data and associated information.

These evaluations should be conducted to provide <u>useful properties information,</u> but not as a demonstration of statistical analysis techniques, per sé. All data sheets which present evaluated information should be accompanied by a presentation of tabular and/or graphical displays of the original information included in the analysis.

Providing answers to specific questions is, in our opinion, one of the real pay-offs and justifications for the recommended program. In performing this function, there is little doubt that the considerations involve topics of current interest. It is usually obvious, during the question and answering process, whether or not the required information is in the desired form. This again, is a true test of the validity of the System's basic design concepts and practical capabilities.

Providing answers to specific questions through an information processing system usually results in the saving of both money and time by either minimizing someone's requirement for conventional, time consuming literature search, or, as is sometimes the case, minimizing the requirement for duplicate, costly testing. Since Government agencies are either directly or indirectly sponsoring most of the work that leads to specific interrogation of the System, the saving in cost and time is always advantageous to the Government.

4.0 ACHIEVING OPERATIONAL STATUS

Tentative scheduling indicates that the recommended System can result in a realistically <u>operational</u> Mechanical Properties Information Center in less than one year. We can make this statement with assurance, since the program involves the evaluation, modification, and improvement of currently active concepts which have already demonstrated their ability to satisfy most of the goals outlined by ASD.

When the System becomes operational, the work phases will differ from those discussed above. We must anticipate that the information processing capability will be dynamic, in that the potential must exist for adding new types of material, their associated information, and properties. As we have stated before, the procedures required by addition of new <u>types</u> of information to the basic System can and are being reduced to a routine operation. <u>Routine operation</u> of the suggested System, therefore, involves effort in the following, definite work areas:

1. Source Document Acquisition

2. Data Input

3. File Merging and Control Inventories

4. Processing and Retrieval

5. Output and Dissemination

6. New Procedures, System and Active File Evaluation

5.0 CONCLUSION

The procedures described above are not intended to provide a general solution to the problem of information processing. They do, however, provide an economical and practical means of developing and implementing a Materials Information Processing System which would have the capability of quickly providing raw data, evaluated data, and pertinent references on both a routine basis and as answers to specific questions.

BIBLIOGRAPHY

Reports

1. ANDREWS, C. & G. BOEHM, "Automatic Data Processing System Minimal Informer"; International Business Machines Federal Systems Division. U. S. Army Signal Engineering Laboratories. ASTIA Document No. 244 196. October 1960.

2. BARGER, GERALD L., "Climatology at Work"; U. S. Department of Commerce, Weather Bureau, Washington D.C., Produced at National Weather Records Center. October 1960.

3. BOOTH, ROBERT & HARRISON WADSWORTH, "The Processes of Documentation"; Center for Documentation & Communication. ASTIA Document No. 211 804. February 1959.

4. BOURNE, CHARLES P.; "Bibliography on the Mechanization of Information retrieval"; Research Engineer, General Systems Department-Stanford Research Institute. February 1958. Supplement I, 1959 - II, 1960 - III, 1961.

5. BRADENBERG, W. & H. C. FALLON, "Selective Dissemination of Information SDL 2 System"; International Business Machines Corporation - Advanced Systems Development Division. April 1961.

6. BRAIN, A. E., G. E. RORSEN & C. P. BOURNE, "Braphical Data Processing Research Study and Experimental Investigation". Stanford Research Institute. ASTIA Document No. 263 117, September 1961.

7. BRAIN, A. E., A. B. NOVIKOFF & C. P. BOURNE, "Graphical Data Processing Research Study and Experimental Investigation"; Stanford Research Institute. ASTIA Document No. 257 307. April 1961.

8. BUCK, CARSON P., R. FORD PRAY III, GERALD W. WALSH, "Investigation and Study of Graphic-Semantic Composing Techniques". Syracuse University Research Institute. ASTIA Document No. 258 974. June 1961.

9. CHERNOFF, HERMAN & GIDEON SCHWARZ, "Storage Policy for Incomplete Record-Keeping". Applied Mathematics and Statistics Laboratories. ASTIA Document No. 261 409. July 1961.

10. GAEL, SIDNEY & EVAN D. STACKFLETH, "A Data Reduction Technique Applied to the Development of Qualitative Personnel Requirements Information (QPI) The Keysort Card System". ASTIA Document No. 243 681. October 1960.

11. GOLDMAN, ALAN J. (Project Manager), BERNICE K. BENDER, "Mathematical Research Related to Information Selection Systems". National Bureau of Standards Report. ASTIA Document No. 262 882. September 1961.

12. GOLDSTEEN, ROBERT, "The Computer Data Format Translator"; Applied Mathematics Laboratory-Research and Development Report. ASTIA Document No. 257 335, June 1961.

13. GREEN, BERT F. JR., ALICE K. WOLF, "Baseball: An automatic Question-Answerer"; Lincoln Laboratory, Massachusetts Institute of Technology. ASTIA Document No. 257 778. June 1961.

14. HAMILTON, J. E., "Experience of Data Collection"; Naval Ship Material Classification. The George Washington University Logistics Research Project. ASTIA Document No. 252 017. February 1961.

15. HAMILTON, J. E., "Experience in Data Collection"; The George Washington University Logistics Research Project. ASTIA Document No. 256 530. May 1961.

16. HUEBNER, WALTER J., AND BERNARD C. RYACK, "Linear Programming and Workplace Arrangement: Solution of Assignment Problems by the Product Technique"; Behavioral Sciences Laboratory - Aerospace Medical Laboratory. ASTIA Document No. 260 462. August 1961.

17. JONKER, FREDERICK, "Descriptive Continum: "Generalized" Theory of Indexing"; Documentation Incorporated. ASTIA Document No. 132 358. June 1957.

18. JONKER, FREDERICK, "Design Considerations of Information Storage and Retrieval Machines"; Documentation, Incorporated. ASTIA Document No. 154 273. April 1958.

19. KELLOGG, D. A., Lt. Col., "Machine Translation - A Review and Analysis Report"; Office of the Chief of Research and Development. ASTIA Document No. 257 839. June 1961.

20. KESSLER, M. M., "An Experimental Communication Center for Scientific and Technical Information"; Lincoln Laboratory. ASTIA Document No. 254 656. March 1960.

21. KESSLER, M. M., "Technical Information Flow Patterns"; Lincoln Laboratory. ASTIA Document No. 261 303, August 1961.

22. KORTE, THOMAS & THOMAS MYERS, "Microfilm Aperture Card System"; Directorate of Engineering Standards, Wright-Patterson AFB. ASTIA Document No. 232 960. 1959.

23. KREITHEN, ALEXANDER, "Mathematical Foundations for a Storage and Retrieval Theory"; Documentation, Incorporated. ASTIA Document No. 132 475. June 1957.

24. LUHN, H. P., "Selective Dissemination of New Scientific Information With The Aid of Electronic Processing Equipment"; International Business Machines Corporation. Advanced Systems Development Division. November 1959.

25. MARON, M. E. & J. L. KUHNS, & L. C. Ray, "Probabilistic Indexing, A Statistical Technique for Document Identification and Retrieval"; Thompson Ramo Wooldridge, Inc. ASTIA Document No. 272 572. June 1959.

26. MELTON, JOHN L.; "Test Program for Evaluating Procedures for the Exploitation of Literature of Interest to Metallurgists"; School of Library Science - Western Reserve University. ASTIA Document No. 263 126. September 1961.

27. MILLER, EUGENE & DELBERT BALLARD; "Comparison of Conventional Grouping and Inverted Grouping of Codes for the Storage & Retrieval of Chemical Data". ASTIA Document No. 154 272. May 1958.

28. MILLER, S. W.; "Fundamental Investigation of Digital Computer Storage and Access Techniques". Stanford Research Institute. ASTIA Document No. 260 117. May 1961.

29. MINSKY, MARVIN; "Steps Toward Artificial Intelligence". Reprinted from the Proceeding of the Ire. January 1961.

30. MITCHELL, M. & C. BURTON; "Coding and Decoding Operations Research Volume II". General Electric Company - Light Military Electronics Department - Advanced Electronics Center. ASTIA Document No. 257 420. June 1961.

31. MOOERS, CALVIN N.; "The Next Twenty Years in Information Retrieval: Some Goals and Predictions". Zator Company. ASTIA Document No. 212 225. March 1959.

32. MOOERS, CALVIN N.; "The Application of Simple Pattern Inclusion Selection to Large-Scale Information Retrieval Systems". ASTIA Document No. 215 434. April 1959.

33. O'CONNOR, JOHN; "The Scan-Column Index. A Book-Form Co-ordinate Information Retrieval System". ASTIA Document No. 236 466. February 1960.

34. POLIACK, SOLOMON L.; "The Role of Data Input in Automatic Data Processing Systems". Rand Corporation. ASTIA Document No. 272 910. December 1960.

35. POSTLEY, J. A. & S. L. POLLACK; "A Data Processing Concept for Air Force Bases". The Rand Corporation. September 1958.

36. PULESTON, D.; "The Technical Information Services of the U. S. Atomic Energy Project". Brookhaven National Laboratory.

37. REES, T. H. & ALLEN KENT: "Study of Indexing and Machine Searching". Center for Documentation & Communication, Western Reserve University, Cleveland 6 Ohio. ASTIA Document No. 213 786. April 1959.

38. RICHMOND, A. W.; "Image Format Considerations in Photographic Intelligence Processing". Data System Project Office, Ramo Wooldridge. ASTIA Document No. 258 149. June 1961.

39. ROSS, DOUGLAS T.; "Computer-Aided Design: A Statement of Objectives:". Electronic Systems Laboratory, Department of Electrical Engineering, Massachusetts Institute of Technology. ASTIA Document No. 252 060. March 1961.

40. SABEH, RAYMOND; "Suggested Procedure for Study and Analysis of Informa-
    tion Requirements". Electronic Systems Division. Air Force Systems
    Command. ASTIA Document No. 260 352. June 1961.

41. SCHREIBER, ALVIN L.; "Measuring the Relevance of an Item of Information to
    the Command of a Complex Man-Machine System". ASTIA Document No. 257 607.
    June 1961.

42. SOLOMONOFF, R. J.; "Research in Inductive Inference for the Period 1 April
    1959 to November 1960". Zator Company. ASTIA Document No. 252 446.
    March 1961.

43. SOLOMONOFF, R. J.; "A Preliminary Report on a General Theory of Inductive
    Inference". Air Force Office of Scientific Research, Air Research and
    Development Command, USAF. Zator Company. ASTIA Document No. 252 445.
    March 1961.

44. STORY, ANNE W.; "Man-Machine System Performance Criteria". Operational
    Applications Office - Deputy of Technology. Electronic Systems Division
    Air Force Systems Command. ASTIA Document No. 260 528. August 1961.

45. STROM, CHARLES A. JR.; "The Increasing Need for High Speed and Reliable
    Digital Communications". Rome Air Development Center - Air Research &
    Development Command USAF, ASTIA Document No. 250 295. February 1961.

46. TAUBE, MORTIMER; "Meaning, Linguistic Structures & Storage & Retrieval
    Systems". Documentation Incorporated. ASTIA Document No. 120 482.
    February 1957.

47. TAUBE, MORTIMER & L. B. HEILPRIN; "The Relation of the Size of the Question
    to the Work Accomplished by a Storage & Retrieval System:". Documentation
    Incorporated. ASTIA Document No. 136 476. August 1957.

48. TAUBE, MORTIMER; "The Distinction Between the Logic of Computers and the
    Logical Storage and Retrieval Devices". Documentation Incorporated.
    ASTIA Document No. 126 458. September 1957.

49. TAUBE, MORTIMER; "An Evaluation of Use Studies of Scientific Information";
    Documentation Incorporated. ASTIA Document No. 206 987. December 1958.

50. WADSWORTH, HARRISON & ROBERT BOOTH; "The Application of Statistical Decision
    Theory to Problems of Documentation". Center for Documentation & Communica-
    tions, Research Western Reserve University. ASTIA Document No. 215 225.
    March 1959.

51. WINTER, K. A. & IRVING LOPATIN; "Materials Information Centers". McGraw-
    Hill Book Company, Incorporated. WADD TN 60-246. February 1961.

52. VON HIPPLE, A. ; "A Center for Materials Science and Technology". Laboratory
    for Insulation Research, Massachusetts Institute of Technology. ASTIA Document
    No. AD 251 032. February 1961.

53. "Fourth Semiannual Report to Congress". National Aeronautics and Space Administration. ASTIA Document No. 252 376. September 1960.

54. "Controlling Literature by Automation". Armed Services Technical Information Agency. ASTIA Document No. 243 000. September 1960.

55. "Federal Research and Development Programs in the 1962 Budget". Executive Office of the President. Bureau of the Budget. January 1961.

56. "Data Line Techniques". Armour Research Foundation of Illinois Institute of Technology, Technology Center. ASTIA Document No. 263 144. September 1961.

57. "A Plan to Reduce Costs of Technical Library Operations in the Department of Defense". United States Naval Ordnance Laboratory. ASTIA Document No. 262 935. September 1961.

58. "U. S. Aeronautics and Space Activities". From President of the United States. ASTIA Document No. 252 375. March 1961.

59. "Data Procesing " The extension of man's sensors and physical capabilities". Amelco, Incorporated. ASTIA Document No. 262 481. September 1961.

60. "Final Technical Report on Development Test Support for Minicard Viewer Processor". Rome Air Development Center, USAF. Zerox Corporation. ASTIA Document No. 263 593. July 1961.

61. "Final Engineering Report on the Development of a Minicard Viewer Processor". Zerox Corporation. ASTIA Document No. 260 073. June 1961.

62. "Panel on Personnel Standards for Military Librarians - Fourth Annual Military Librarian's Workshop". ASTIA Document No. 243 001. October 1960.

63. "Document Grouping". Information Systems Branch, Office of Naval Research. ASTIA Document No. 257 575. September 1959.

64. "An Operations Research Study of the Dissemination and Use of Recorded Scientific Information". Office of Scientific Information. National Science Foundation. ASTIA Document No. 251 808. March 1961.

65. "Final Report Machine Translation Studies of Semantic Techniques". Intelligence Laboratory, Rome Air Development Center. ARDC, USAF. ASTIA Document No. 256 355. May 1961.

66. "Final Report on Types Page Reader". Control Instrument Company, Inc. ASTIA Document No. 263 325. September 1961.

67. "Hearings Before the Committee on Aeronautical & Space Sciences United States Senate". United States Government Printing Office. March 1961

68. "Quarterly Progress Report-Information Processing - Division 5". Lincoln
Laboratory, Massachusetts Institute of Technology. ASTIA Document No. 256 371.

69. "Conference on Multiple Aspect Searching for Information Retrieval, Washington,
D.C.". Armed Services Technical Information Agency. ASTIA Document No.
147 491. February 1957.

70. "Machine Language Translation Devices System". U. S. Army Signal Research and
Development Laboratories, Sixth Quarterly Progress Report. ASTIA Document
No. 256 469. May 1961.

71. "Final Technical Report on Converter, Speech-to-Digital". Scope Incorporated.
ASTIA Document No. 251 409. February 1961.

72. "Brochures on Electronic Computers and Instruments". Moscow. ASTIA Document
No. 258 459. June 1961.

73. "Reorganization of Soviet Science". Air Information Division. ASTIA Document
No. 257 914. June 1961.

74. "The Institute for Cooperative Research". Common Programming Language Task-
Automatic Code Translation System (ACT). The Moore School of Electrical
Engineering. University of Pennsylvania. ASTIA Document No. 248 111.
December 1960.

75. "Information Storage & Retrieval". OTS Selective Bibliography. U. S. Department
of Commerce. A bibliography of reports listed in the two OTS semi-monthly
abstract journals: U. S. Government Research Reports and
Technical Translations.

76. "Nonconventional Technical Information Systems in Current Use. No. 2"
National Science Foundation. March 1960.

77. "Current Research and Development in Scientific Documentation No. 8." National
Science Foundation. March 1960.

78. "Current Research and Development in Scientific Documentation No. 9". National
Science Foundation. Nov. 1961.

79. "Specialized Science Information Services in the United States". National
Science Foundation. November 1961.

80. "Documentation, Indexing, and Retrieval of Scientific Information". A Study
of Federal and Non-Federal Science Information Processing and Retrieval
Programs. Documents No. 15 and 113. March 1961.

81. "Scientific Information Activities of Federal Agencies". National Science
Foundation. U. S. Government Printing Office, NSF 60-9. Veterans Administration,
NSD 61-22. Tennessee Valley Authority, NSF 60-44. U. S. Department of
Commerce - Part II, NSF 60-58. U. S. Department of Commerce - Part III, NSF 60-59.
Federal Communications Commission, NSF 61-112. U. S. Department of Agriculture.
NSF 58-27.

82. "Quarterly Progress Report - Information Processing - Division 5". Lincoln Laboratory. Massachusetts Institute of Technology. ASTIA Document No. 252 199. December 1960.

83. "Quarterly Progress Report - Information Processing - Division 5". Lincoln Laboratory. Massachusetts Institute of Technology. ASTIA Document No. 260 633. June 1961.

84. "More Effective Organization and Administration of Materials Research and Development for National Security". Committee on Scope and Conduct of Materials Research. National Academy of Sciences - National Research Council. 1960.

85. "Quarterly Progress Report - Information Processing - Division 5". Lincoln Laboratory. Massachusetts Institute of Technology. ASTIA Document No. 263 607. September 1961.

Periodicals

1. "Control Engineering". McGraw-Hill Publication. Monthly.

2. "Scientific Information Notes". National Science Foundation Vol. 3, 1 thru 5. February thru November 1961.

3. "Data Processor". International Business Machines Corporation. Vol. 6, April, May and June, 1961.

4. "Reviews of Data on Research & Development". National Science Foundation. NSF-60-10 and NSF 60-81.

5. "Technical Reports". U. S. Department of Commerce Business & Defense Administration, Office of Technical Services. Published monthly.

6. "Data Processing". American Data Processing, Inc. 22nd floor book tower. Detroit 26, Michigan. 1961.

7. "In-Plant (Offset Printer)". Published Bi-Monthly -- Data Processing Publishing Company. Jan. thru June 1961.

8. "Data Processing Information". International Business Machines Corporation. Monthly.

9. "Data Processing Digest". Published by Canning, Sisson and Associates, Inc. Monthly.

10. "Technical News, National Bureau of Standards". U. S. Government Printing Office. Volumes 1-12, Jan. - Dec. 1961.

11. "Army Research and Development". Research and Development Headquarters. Monthly.

12. "Materials Research and Standards". American Society for Testing Materials. Monthly.

13. "Photo Methods for Industry (PMI) Gellert-Wolfman Publishing Corporation. Monthly.

14. "Library Research in Progress". U. S. Department of Health, Education, and Welfare. Numbers 3, 4, 5 and 6. April and September of 1960, March and December 1961.

15. "Research Highlights of the National Bureau of Standards". U. S. Department of Commerce. Monthly.

16. "Pert Data Processing Lesson Plan Handbook for Technicians". Special Projects. Office of Bureau of Naval Weapons. Revised November 1960.

Books

1. "Transmission of Information", Robert M. Fano. Massachusetts Institute of Technology. 1961.

2. "Towards Information Retrieval", R. A. Fairthorne. Butterworths, London. 1961.

3. "Computers and Common Sense", Mortimer Taube. Columbia University Press. 1961.

4. "Information Storage and Retrieval", Mortimer Taube and Harold Wooster. Columbia University Press, 1958.

Aeronautical Systems Division,Dir/Materials and Processes, Applications, Lab. Wright-Patterson AFB, Ohio
Rpt Nr   ASD-TDR-62-819. DEVELOPMENT AND IMPLEMENTATION OF A MATERIALS INFORMATION PROCESSING SYSTEM. Final Report, Jan 63. 24 p. incl 105 refs.   Unclassified Report

A program is described for acquisition, storage, analysis, and dissemination of materials information. A specific and representative portion of the Materials Information System is used as a model and discussed in detail. The System is designed to store individual test data and associated

(over)

descriptive information. It therefore provides the capability for data analysis based on complex interactions, graphic or tabular display of data, and more conventional bibliographic output.

1. Information processing
2. Materials information.
I. AFSC Project 7381, Task 738103
II. Contract AF33(616)-8046
III. Belfour Engineering Company, Suttons Bay, Michigan
IV. A. J. Belfour
V. Aval fr OTS
VI. In ASTIA collection

Aeronautical Systems Division,Dir/Materials and Processes, Applications, Lab. Wright-Patterson AFB, Ohio
Rpt Nr   ASD-TDR-62-819. DEVELOPMENT AND IMPLEMENTATION OF A MATERIALS INFORMATION PROCESSING SYSTEM. Final Report, Jan 63. 24 p. incl 105 refs.   Unclassified Report

A program is described for acquisition, storage, analysis, and dissemination of materials information. A specific and representative portion of the Materials Information System is used as a model and discussed in detail. The System is designed to store individual test data and associated

(over)

descriptive information. It therefore provides the capability for data analysis based on complex interactions, graphic or tabular display of data, and more conventional bibliographic output.

1. Information processing
2. Materials information.
I. AFSC Project 7381, Task 738103
II. Contract AF33(616)-8046
III. Belfour Engineering Company, Suttons Bay, Michigan
IV. A. J. Belfour
V. Aval fr OTS
VI. In ASTIA collection