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MAGNETIC MEASUREMENTS, CALIBRATIONS, and STANDARDS:

Report on a Survey

October 1984

Electromagnetic Technology Division
National Bureau of Standards
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U.S. DEPARTMENT OF COMMERCE, Malcolm Baldrige, Secretary

NATIONAL BUREAU OF STANDARDS, Ernest Ambler, Director

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by

F. R. FICKETT
ELECTROMAGNETIC TECHNOLOGY DIVISION

1. BACKGROUND

In 1983, a decision was made to evaluate the interest in developing a competence in magnetic measurements within NBS. There had been a program several years earlier that had provided calibration services to industry and to other agencies, but it was terminated, primarily due to an NBS-perceived lack of interest on the part of the users and to budgetary constraints. In the following years, inquiries from the private sector indicated that perhaps it was time to reassess this decision.

Our small group in the Center for Electronics and Electrical Engineering has maintained a competence in magnetics throughout the years with work for other government agencies and with funds from a program of grants for postdoctoral research. At the present time, we are receiving one or more requests a week for information and data on magnetic measurements and magnetic properties. We have always managed to respond to such requests, but at the expense of other work. It was suggested that we might be the appropriate group to investigate the actual need for such services. There is, thus, little doubt that we started the program with a small bias.

Be that as it may, there were several factors operable that made a review of the question quite reasonable. First, and probably most important, was the enormous increase in the use of magnetics in the computer and computer-related industries, especially magnetic media for data storage and magnetic devices for accessing, storing, and processing these data.* In addition, rapid developments in the field of permanent magnets and of new ferromagnetic alloy materials, such as the amorphous ferromagnets both soft and hard, had brought new life to this area of magnetics as well.

Magnetism is a unique field of science. Its historical development has led to a plethora of units that has proven to be the bane of many a student of physics and engineering. It is a difficult field, and one in which few organizations can afford to maintain any depth of competence.

Our approach to the evaluation of the need for a NBS magnetics program was to develop a detailed (five pages) questionnaire and distribute it to those that we felt would be most affected by such a program: the members of the IEEE Magnetics Society, the Magnetic Materials Producers Association, the

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*NBS, through the Institute for Computer Sciences and Technology and the Office of Standard Reference Materials, does provide standard tapes and a standard flexible disk cartridge for output signal amplitude calibration of magnetic recording systems.

appropriate ASTM and ANSI committees, the manufacturers of magnetic instrumentation, standards laboratories, and numerous consultants. In all, about 2000 questionnaires were mailed. The number of responses was significantly greater than expected -- nearly 500. Furthermore, about one quarter of the respondents not only replied to all of the questions, but also took the time to write lengthy additional comments.

In the report that follows, we present the results of this survey. First we outline the questionnaire structure and explain what we hoped to learn from each of the sets of questions. Next we give a summary of the responses and a synopsis of the additional information provided by the respondents. Finally, we present our analysis and a few conclusions.

2. THE QUESTIONNAIRE

A copy of the questionnaire is included here as Appendix A. The final form was arrived at in consultation with officers of the various organizations mentioned above, the center staff, G. Tassey of the program office (for economic assessment and impact questions), and numerous others mentioned in the Acknowledgments.

The questionnaire is divided into five major parts. The first (preface and section A) asks for information on the respondent's organization, including some financial information. The second (sections B, C, and D) explores which properties are measured, instruments used, frequency range, accuracy and precision required, method and frequency of instrument calibration, and types of materials involved. The questions are structured to indicate whether a respondent is a user, instrument manufacturer, or provider of standards. The third section (E) determines the degree of interaction of the respondent's organization with the various standards-setting organizations. Included here is a key question to determine the extent to which traceability to NBS is important to their operation. The fourth part (sections F and G) asks a number of questions regarding the extent and type of participation by NBS that the respondent would find beneficial. The questions here are quite specific, dealing with such matters as the particular areas of involvement (data compilations, calibrations, measurement facilities, or standard reference materials (SRMs)) as well as the potential impact of these services. Several of the questions allow for comments to the effect that it would be best if NBS were not involved in a particular area (or at all for that matter). A final group of questions (sections H and I) determines the interest in a workshop type of meeting related to the topics and provides space for further comments.

For nearly every question, a response of "other" was provided. In most instances, these responses were tabulated manually and are discussed in the text.

A total of 487 complete questionnaires was processed. Another 20 or so were used only in part. Most of these were received from retired scientists who, while not able to respond to the specific questions, did take the time to provide numerous very valuable comments based on their experience in the various fields.

3. TABULATION OF THE RESPONSES

Here we present a summary of the results from the survey. Processing of the large number of returns required creation of a computerized data base and many hours of data entry. With the programs now written and operating, we feel that we can answer almost any question that might be asked regarding the responses. It is neither practical nor desirable to include all permutations in this report, but the reader should feel free to contact the author with specific questions.

The data presentation below are divided into separate sections based on the major categories of the questionnaire. Percentages are usually used to indicate the response to a particular question. Unless otherwise stated, this percentage is based on the total number responding to that question, not on the total of all responses to the survey. To keep this report to a manageable size, many of the questions are not discussed in detail, but are reported only as overall percentages. We have tried to provide detailed information on those that have a significant bearing on our conclusions.

a. The Respondents

The organizations represented by the respondents are listed in Appendix B. There is a heavy preponderance of computer-related companies, indicating the importance of those fields today (a significant departure from the situation in the days of the earlier NBS magnetics facility). But these are by no means the only ones. The steel industry, aerospace companies, power-related companies, high-tech firms of various sorts, consultants, national laboratories, and university research laboratories are represented here. In the case of larger organizations, multiple responses were often received. These multiple responses are each treated separately in the tabulation, since most often they are from quite different parts of the organization.

A total of 481 respondents designated the type of organization. The breakdown (in percentage response) is as follows:

Computer related	38
Materials producer	14
Electronic components	10
Instrument manufacturer	7
University	7
Aerospace	5
Fabricator	5
Electric power	3
Government	3
National laboratory	1
Standards laboratory	<1
Other	15

The sum is greater than 100%, since some organizations fall into more than one category. The category "other" includes a tremendous variety of organizations such as telephone, oil, power tool, automotive, private research, and consultants.

b. Properties

The question asked about 17 properties ranging from the common (flux density) to the esoteric (magnetocrystalline anisotropy). As a percentage of total respondents to the questionnaire,

87% listed themselves as routinely measuring one or more of the properties;

9% listed themselves as manufacturers of instruments that measure the property in question;

7% listed themselves as providers of standards for measurement of the property (but often only for in-house use).

The properties most often measured (>300 responses) were flux density (B), field intensity (H), and B-H loop. The next category (>200 responses) included flux, coercivity, magnetization, permeability, remanence, and saturation. No property on the list received less than 88 responses. The 48 responses of "other" to the question covered a wide range of properties. Most were related to magnetic recording (density, overwrite, head output, bit error rate), but there were a number involving microwave properties (ferromagnetic resonance, spin waves), and more conventional ones (magnetoresistance, Hall effect, loop squareness).

Another question in this group asked for the frequency range in which the properties were most often measured. Forty percent measured at dc; 28% below 100 Hz; 32% between there and 100 kHz; 24% from 100 kHz to 1 GHz; and only 5% above that. Again, multiple entries make the total much greater than 100%. The rather uniform distribution of responses over the frequency spectrum and the large number of multiple responses (>33%) was unexpected and has significant implications for potential NBS services.

Everyone who responded to the measurement question also responded to the question regarding the accuracy generally required in their measurements. The breakdown is as follows:

Accuracy Required in %	% of Respondents
>10	2
1-10	60
0.1-1	37
0.01-0.1	4
<100 ppm	2

In general, great accuracy is not called for in the area of magnetic measurements. However, 10% of the respondents indicated that, for some measurements, extreme accuracy (<0.1%) was required. No listed property escaped an entry in this category. The properties most mentioned (10 or more respondents) were flux density, field intensity, and saturation. Six to nine respondents listed remanence, coercivity, magnetization, permeability, and B-H loop.

c. Instruments

There are numerous techniques available for measuring the various properties. The choice among them is dictated by many considerations such as material, sample size, desired accuracy, time required for a measurement, cost of the instrumentation, and amount of training required of the operator. The questionnaire presented a list of 30 instruments that are commonly used in the field of magnetics. Again, as a total percentage of those responding to the questionnaire

89% are users of the instruments and are discussed in more detail below;

23% are manufacturers, most make electromagnets of various sorts or magnetic recording instrumentation, many make instruments only for their own use;

12% provide standards or calibration service, again frequently for in-house use only. Most are in the magnetic recording media category, with permanent magnets in second place and hysteresigraph standards third.

Of the users, more than 200 use one or more of the following: iron-core electromagnets, permanent magnets, Hall effect gaussmeters, search coil fluxmeters, and degaussers. In addition, between 100 and 200 respondents routinely use resistive solenoids, vibrating sample magnetometers, hysteresigraphs, magnetizers, demagnetizers, standard magnets, magnetic moment standards, and magnetic recording media standards.

In this last group there are three surprises in terms of heavy usage - the standard magnets, moment standards and the vibrating sample magnetometer (VSM). The first of these require recalibration on a regular (but infrequent) schedule. The nickel sphere moment standard is only available from NBS as far as we know, although specialized nickel standards for hysteresigraph calibration are provided by the University of Dayton, and this response indicates a wider usage than expected. Finally, the widespread use of the VSM is interesting in that it is a very sophisticated instrument, requiring specialized calibration standards. NBS now provides a few of these in the form of SRMs, but only 22 respondents say that they use them. Similarly, volt-second standards are the conventional method for calibrating fluxmeters, yet only 39 report using them (as opposed to 202 users of fluxmeters).

None of the listed instruments was cited less than 20 times. The "other" category produced 15 entries, nearly all specialized instruments related to magnetic recording.

Nearly all users responded to our question relating to the source and frequency of calibrations for their instruments. In-house laboratories provide 59% of the calibrations and 34% use an external service. This implies that 7% never have their instruments calibrated, although only 1% admitted it on the frequency-of-calibration question. Regarding this question, 8% have calibrations done only when the instrument is returned for repair, 33% have occasional calibrations, and 54% calibrate on a regular schedule.

d. Materials

The purpose of this question was to determine which of the many magnetic materials were most used. Nearly everyone (475) listed at least one, but most listed several. We used 8 categories for this question with the following responses:

Material	% Response
Ferrites	79
Permanent magnets	70
Soft ferrous alloys	66
Recording media	61
Thin films	50
Powders	46
Amorphous alloys	40
Other	6

The "other" category included superconductors, minerals of various sorts, magnetic colloids, superparamagnetic materials, magnetic insulators and semiconductors to name a few.

e. Standards Organizations

Paper standards, such as those available from ASTM, are used by 35% of the respondents. Interaction with standards groups is claimed by 73%, with 57% indicating active committee participation. The most often mentioned groups are: IEEE (38%), ANSI (56%), ASTM (38%), MMPA (2%), and NCSL (1%). The "other" category (12%) included about a dozen organizations.

f. Traceability to NBS

Here we attempted to assess whether or not a lack of traceability to NBS was ever a problem to these organizations. Of the total responding to the survey, 33% indicated that it was. Five categories of problems in this regard were offered. The responses:

Reason	% Response
Compatibility assurance	73
Military contract requirements	23
Other	14
Trade equity	11
Foreign customer requirements	9

The "other" category mostly included problems with company-company or company-vendor agreement.

g. Areas of Possible NBS Involvement

Here we presented seven broad areas in which NBS might play a role helpful to the magnetics community. We asked the respondents to rate each of these areas as either extremely useful (E), useful (U), or not useful (N). More than 90% contributed to this section. In the following tabulation, we list each category and the number responding with each rating as a percentage of those responding to that category. The total responses to that category follow the category title in parentheses. The column headings are as given in parentheses above.

Area of Involvement	E	U	N
Develop new measurement techniques (424)	42	52	5
Make measurements on request (415)	44	48	8
Provide traceability (412)	47	43	10
Compilations of data (391)	31	56	12
Instrument calibration (388)	27	57	16
Reference magnet calibration (373)	31	50	19
Coil calibration (360)	23	54	23
Accurate field facility (365)	24	46	30
Standard Reference Materials			
Ferrite SRM (363)	42	47	11
Magnetic media SRM (350)	54	30	15
Amorphous alloy SRM (294)	26	51	23
Magnetic steel SRM (319)	31	44	25
Magnetic thin film SRM (288)	37	37	26
Other SRM (30)	39	30	30

In the "other SRM" category, a large number requested permanent magnet materials of various sorts. Other SRM requests were for ferrofluids, shielding alloys, square-loop materials, more paramagnetic materials, diamagnetic materials, and coercivity standards to name a few.

A more complex question was included in this section in which we inquired as to which properties should be reported for a given SRM material and to what accuracy. For the five categories given in the table, we received a total of 847 responses plus an additional 44 suggesting other SRMs and appropriate properties. A discussion of our analysis of this question would be a report in itself; one that we leave for another time.

We asked, in a separate question, if there were other services that people would like to have available at, or from, NBS. A total of 49 responses was received (10% of the total) covering a wide range of desires. They cannot all be listed here, but we give a few that serve to indicate the type of request received:

Maintain a core of excellence in measurement techniques for support of industry. Develop new techniques of measurement as new properties become important.

Provide a telephone consultation service for discussion on specific measurements and technical literature relevant to measurements.

Serve as a referee in industry comparison testing. Provide guidance for industry standards organizations. Review and coordinate specifications for magnetic products from other government agencies.

Provide a magnetic measurements "handbook" that would include techniques, limitations, and relative advantages of various techniques.

Develop a data base on all magnetic materials. Investigate biological effects of magnetic fields.

Create a service laboratory for evaluating new materials, providing accurate measurements and a general testing service.

Standardization of magnetics CAD (Computer Aided Design) systems. Develop an input that would cause standard output from magnetics calculation codes. Develop computer programs for calculation of flux leakage.

Provide a standard toroid for B-H loop measurement, a saturation magnetization standard, and more standards for VSM calibration. Provide coercivity standards.

Promote standardization of magnetic units.

Clearly there is much that could be done that would be of interest to the magnetics community.

In order to evaluate the negative side of NBS involvement, we asked if anyone saw the potential for conflict with private organizations should NBS undertake any of the services described in the section. A total of 44 responses was received (10% of the total), but not all of them were negative in spite of the wording of the question. Most of the negative responses referred to the problems that would be faced by private organizations offering calibration and measurement services for a fee. Several made the point that entry of NBS into some of these areas would not automatically lead to conflict any more than it has in many other fields in which NBS provides such services. One person (from the computer industry) wrote a long and very thoughtful letter to the effect that NBS standards might add extra testing to his routine and thus increase costs and delivery times. In addition, he suggested that some foreign countries would probably issue conflicting standards that would further complicate his business. Another respondent wrote that he felt that industry itself could, and should, provide calibration services if traceable reference standards were available from NBS.

In summary, it seems that there are legitimate concerns on the part of some respondents that would have to be addressed in the development of a magnetics program at NBS, but the overwhelming attitude is that such services are sorely needed now.

Another matter that was mentioned in several instances was that of making the laboratory available to an extent as a user facility. While not mentioned specifically as an option in the questionnaire, several comments did address this possibility. We have explored this concept at some length with L. Rubin and others associated with the Francis Bitter National Magnet Laboratory, which is a model user facility in our opinion. They encouraged us to consider such an option and not only saw no conflict with their operation, but felt that it would provide a place to which they could refer many requests that they get, but cannot handle at the present. Such an option also would provide a solution to many of the concerns expressed by respondents regarding the lack of training available in magnetics in the U.S. at all levels from technician to advanced-degree staff.

h. Impact

In order to evaluate what effect NBS involvement might have on the organizations surveyed, we included a question that asked what impact such an action would have on their business. Six specific possibilities (all positive) were suggested along with the ubiquitous "other." A total of 86% of all respondents contributed to this question, most with more than one entry (in fact, 54% of those responding to this question used three or more entries). A summary of the results is given below.

Proposed Impact	% Responding
Improved product reliability	63
Improved ability to meet customer specifications	63
Improved product features	46
Increased ability to compete in foreign markets	37
Increased production yields	35
Cost reductions	28
Other	13

Once again, the list of responses to the "other" entry was varied, to say the least. In one way or another, they nearly all addressed some aspect of improvement in technical "communication" and believability of critical measurements and data. There is no question but that essentially all of those surveyed feel that NBS involvement in magnetics will have a significant impact on their business.

i. Workshop

Our request as to how many of the respondents would be interested in attending a workshop to address some of the concerns related to magnetic measurements and standards was well received with 67% indicating an interest. However, when asked if they would be interested in presenting a paper or serving on a discussion panel, the percentage dropped significantly, to 29%. This is probably to be expected as it seems that most felt they had much to learn from such attendance, but not as much to contribute.

4. ANALYSIS AND CONCLUSIONS

The results of the survey seem unequivocal -- a magnetics program at NBS would be welcomed by nearly all of the respondents. The population surveyed is, of course, the one that most needs the proposed service. There is also a much larger group (general electronic instrument manufacturers, military laboratories, utilities, the semiconductor industry, etc.) that would be affected by such a service, and it was not practical to survey them as well. Random inquiries of this group, however, indicate a similar response to that reported here. Questions to evaluate the willingness of the organizations to pay for the service were removed from the questionnaire early in the process, since they were deemed to be too vague by the early reviewers. This vagueness was unavoidable, since we had no way of determining the cost of the services proposed. The general response of this early group was that they would be willing to pay a "reasonable" fee, but certainly not the entire cost of creating and maintaining the laboratory.

Balanced against this enthusiasm is the perceived size of the group that would benefit. This is a matter that is certainly open to debate. Also, there is the matter of the cost of creating a major new facility, housing state-of-the art equipment, in the present economic climate. This laboratory would almost certainly require 8-10 people at various levels and $0.5M in equipment money. The small amount of equipment that presently exists at NBS is mostly outdated and certainly not competitive with that now resident in the more technically competent industrial facilities.

Whether a small initial effort could be successful as a base upon which to build in future years is questionable. If it is too small or too poorly equipped, the desired impact on industry would not be possible. We feel that there is a minimum level below which it is not practical to proceed. At this level, the choice of projects would become extremely critical. Calibrations would not be possible, and development of all but the most important SRMs would be deferred. This minimum effort would concentrate nearly exclusively on the development of measurement techniques and dissemination of this information to users through publications.

The survey results agree with our long-held position on the structure of such a program, namely, that we need a strong capability in instrumentation and magnetics research before a calibration and standards facility is created. The most requested area of involvement is research on new measurement techniques with help in the determination of magnetic properties a close second.

The strong request for support in the magnetic media area was somewhat unexpected, since that is one field in which industry has an excellent capability. Furthermore the new Center for Magnetic Recording Research formed by the industry (located at the University of California at San Diego) is now a reality. The requested services from NBS appear to be generic, pointed toward long-term evaluation of measurement techniques and creation of methods and materials for resolution of measurement-related disputes.

We feel that the survey results lead to the following major conclusions regarding a full-scale magnetics facility at NBS:

It should have the capability to measure all of the common magnetic parameters including the ability to handle unusual shapes and sizes of samples. Emphasis should be on the truly basic parameters (B, H, M) in all their aspects, but the more exotic ones (magnetocrystalline anisotropy, magneto-optical effects, etc.) should not be ignored. The measurement capability should cover a frequency range from dc to at least 1 GHz.

Special emphasis should be given to the vibrating sample magnetometer in its various forms and in the creation of appropriate SRMs for this instrument because of its widespread use in industry.

A measurement service for the public may be essential, at least initially. We feel that our ultimate goal should be to assist industry by providing well-documented measurement techniques and essential SRMs that allow them to perform their own measurements, with NBS providing direct services in only the most critical areas. An active industrial associate program might be helpful in this regard.

Providing for some form of traceability of measurements to NBS should be given high priority. Helping manufacturers of magnetic instrumentation develop a calibration capability traceable to NBS would be valuable and would perhaps eliminate the need for a full-scale calibration facility at NBS.

Extreme measurement accuracy is not generally necessary, 1% being adequate in most cases. Even this level is not easily achieved in many measurements. This is not to say that extreme accuracy is never required; NMR is a field where quite the opposite is true.

A capability in modern techiques for computer modeling of fields is needed. Methods for testing results from the various models, both analytic and experimental, should be developed.

We do not see the need for a workshop as a source of further input to this analysis. Certainly, if a program in magnetics is developed within NBS, such a meeting would be of prime importance, both to gather the most recent information on needs and desires and as a method of introducing the program to the outside world. From the responses and comments received on this topic, it would appear that the best forum for such a workshop would be in connection with one or more of the magnetics meetings (Magnetism and Magnetic Materials, San Diego, November 1984; INTERMAG, St.Paul, April 1985; or International Conference on Magnetism, San Francisco, August 1985).

5. ACKNOWLEDGMENTS

A very special acknowledgement is due Mrs. V. Grulke for her participation in this project. From learning the intricacies of the data base management system to many long hours of data entry and even longer hours of extracting the "extra" comments of the respondents from the questionnaires, she maintained her normal good humor and high spirits. This job could not have been done nearly as quickly or as well without her help.

As with any undertaking of this magnitude, many people provided assistance and encouragement. We are indebted to the staff of the Superconductors and Magnetic Materials Group, especially R. Goldfarb and A. Clark, for their participation. Comments from J. French and J. Mayo-Wells were very helpful. B. Taylor and other members of his division provided valuable information on calibrations. G. Tassey of the program office provided an excellent education in the ways of asking economic questions. M. Hogan of ICST contributed information on the standardization of magnetic media and on the activities of NBS and ANSI in this area. C. Johnson, President of the IEEE Magnetics Society, not only provided input and encouragement, but also arranged for us to receive already-processed mailing labels for the nearly 2000 members of his society. T. Dolan of the Magnetic Materials Producers Association arranged for his executive committee to review the questionnaire. The entire membership of ASTM committee A06, under the chairmanship of M. Boenitz, provided many of the early ideas regarding measurement of the soft steels and similar materials.

APPENDICES

OMB Approval No: 0652-0019
Expiration Date: January 1984

UNITED STATES DEPARTMENT OF COMMERCE

National Bureau of Standards

QUESTIONNAIRE
ON
MAGNETIC MEASUREMENTS, CALIBRATIONS, AND STANDARDS

As a result of inquiries received from industry, we are attempting to make an assessment as to what role, if any, the National Bureau of Standards (NBS) should play in the area of magnetics. We would appreciate it if you would help us by responding to the questions below and adding any further comments that seem appropriate. Please note that NBS is not a regulatory agency nor, as a matter of policy, does it compete with private industry. Our goal is to evaluate areas of magnetics in which industry would welcome assistance from NBS. If you have questions, please call Dr. Fred R. Fickett at NBS in Boulder, Colorado (303-497-3785). Probably not all questions will be applicable to your organization; just ignore those that are not. In each response area check as many entries as apply.

Please indicate any correction to the mailing label.

Name of person responding:______________________________ Tel: ____________________

Are you willing to be contacted by telephone regarding your responses? __Y __N

NBS-1208
(11-83)

A. Your Organization

1. Aerospace __
2. Computer Related __
3. Electric Power __
4. Electronic Components __
5. Fabricator __
6. Government __
7. Instrument Manufacturer __
8. Materials Producer __
9. National Laboratory __
10. Standards Laboratory __
11. University __
12. Other ____________________

Number of employees in Research and Development __________.

Approximate total yearly sales __________.

Approximate total yearly Research and Development expenditures __________.

B. Properties of Concern

Circle M if your organization manufactures instruments to measure the property, U if the property is routinely measured, and S if your organization provides physical standards.

1. Flux (ϕ)	M	U	S
2. Flux density (B)	M	U	S
3. Field intensity (H)	M	U	S
4. Coercivity (H_c)	M	U	S
5. Magnetization (M)	M	U	S
6. Permeability (μ)	M	U	S
7. Susceptibility (χ)	M	U	S
8. B-H loop	M	U	S
9. Energy product	M	U	S
10. Remanence (B_r, M_r)	M	U	S
11. Saturation (B_s, M_s)	M	U	S
12. Core loss	M	U	S
13. Other hysteresis losses	M	U	S
14. Domain effects	M	U	S
15. Magnetostriction	M	U	S
16. Magnetocrystalline anisotropy	M	U	S
17. Magneto-optical effects	M	U	S
18. Others ____________________	M	U	S

The measurements are primarily made at:
dc <100 Hz 0.1-100 kHz 100 kHz-1 GHz >1 GHz

In general, the accuracy required of our measurements is in the range:
>10% 1-10% 0.1-1% 0.01-0.1% <100 ppm.

Is extreme accuracy (<0.1%) required for <u>any</u> measurements? Enter numbers from the list (B) above. ____________________

continued

C. Instruments and Standards

Circle M if your organization manufactures these, U if they are used routinely, and S if your organization provides physical standards or calibration.

1. Magnet systems -	Electromagnet with iron	M	U	S
	Solenoidal, resistive	M	U	S
	Superconducting	M	U	S
	Permanent magnet	M	U	S
2. Magnetometers -	Force balance	M	U	S
	SQUID	M	U	S
	Fluxgate	M	U	S
	Proton precession	M	U	S
	Vibrating sample	M	U	S
	Vibrating coil	M	U	S
	Nuclear magnetic resonance	M	U	S
3. Gaussmeters -	Hall effect	M	U	S
4. Fluxmeters -	Search coil	M	U	S
	Rotating coil	M	U	S
5. Coercimeters		M	U	S
6. Permeameters		M	U	S
7. Loop measuring -	Hysteresigraph	M	U	S
	Epstein frame	M	U	S
	Other ____________________	M	U	S
8. Magnet processing -	Magnetizers	M	U	S
	Demagnetizers	M	U	S
	Calibrators	M	U	S
9. Degaussers		M	U	S
10. Magneto-optic devices -	Kerr effect	M	U	S
	Faraday effect	M	U	S
11. Microwave -	Ferromagnetic resonance	M	U	S
12. Standard magnets		M	U	S
13. Volt-second standards		M	U	S
14. Magnetic moment standards (e.g., nickel)		M	U	S
15. Susceptibility standards (e.g., Aℓ, MnF_2)		M	U	S
16. Magnetic recording media standards		M	U	S
17. Other ____________________		M	U	S

Calibrations of instruments is done {never __, only when returned to manufacturer for repair __, occasionally __, on a regular schedule __} by {in-house laboratory __, external service __}.

continued

D. Materials

Indicate how often your organization deals with each of the following materials. Circle A for all the time, O for occasionally, and N for never.

1.	Soft ferrous alloys	A	O	N
2.	Ferrites	A	O	N
3.	Permanent magnets	A	O	N
4.	Powders	A	O	N
5.	Thin films	A	O	N
6.	Recording media	A	O	N
7.	Amorphous alloys	A	O	N
8.	Other ________________	A	O	N

E. Calibration and Standards

1. Does your organization use paper standards, such as those available from ASTM, for magnetic measurements? __Y __N

2. What standards groups does your organization interact with?
a) ASTM __, b) IEEE __, c) ANSI __, d) NCSL __, e) Other __________

3. In which groups is there active committee participation?
a) ASTM __, b) IEEE __, c) ANSI __, d) NCSL __, e) Other __________

4. Is lack of traceability of measurement to NBS ever a problem? __Y __N

If so, is this because of:
a) Requirements of foreign customers __
b) Military contract requirements __
c) Compatibility assurance __
d) Trade equity __
e) Other ____________________ __

F. Possible Areas of NBS Involvement

Please indicate your feelings as to the usefulness of each of the following possible outputs from an NBS magnetics program. Circle E for extremely valuable, U for useful, or N for not useful.

1.	Compilations of data (reviewed and evaluated)	E	U	N
2.	Research on new measurement techniques	E	U	N
3.	Establishment of a facility to provide precise field and field gradient configurations	E	U	N
4.	Calibration of a) Instruments	E	U	N
	b) Reference magnets	E	U	N
	c) Coils	E	U	N
5.	Traceability of measurements and calibrations	E	U	N

continued

6. Standard reference materials for:

a) ferrites	E	U	N
b) steels	E	U	N
c) amorphous alloys	E	U	N
d) magnetic media	E	U	N
e) thin alloy films	E	U	N
f) Other ____________________	E	U	N

In the list below please indicate the properties (from the list in part B) that should be determined for that standard reference material. Enter the number(s) from part B. Also indicate that range of characterization accuracy that would be adequate for your needs with the code: A = ppm level; B = 0.01-0.1%; C = 0.1-1%; and D = 1-10%.

Material	Properties	Accuracy
a) ferrites	______	______
b) steels	______	______
c) amorphous alloys	______	______
d) magnetic media	______	______
e) thin alloy films	______	______
f) Other __________	______	______

7. Measurement of magnetic properties of specific materials upon request. E U N

8. Are there other services that would be desirable?

9. Do you see potential conflict with private organizations in any of the services described in 1-9 above? __Y __N

Please explain if "yes" was marked.

G. Impact

Which of the following contributions to your organization and its products would you anticipate as a result of NBS involvement?

1. Improved product features __
2. Cost reductions __
3. Improved product reliability __
4. Increased production yields __
5. Improved ability to meet customer specifications __
6. Improved competitive position in foreign markets __
7. Other ____

continued

H. Workshop

1. Would you be interested in attending a 1-2 day workshop on magnetic measurements, calibrations, and standards? __Y __N

2. Would you consider presenting a paper or serving on a discussion panel? __Y __N

I. Additional Comments

Thank you for your assistance.

APPENDIX B - PARTICIPATING ORGANIZATIONS

Listed here are most of the organizations represented by the responses to the survey.

3M
A. O. SMITH
A&E DATA TECHNOLOGY
ACME ELECTRIC
ACTON COMPUTER TECHNOLOGY
ADVANCED TECHNOLOGY GROUP
ADVANCE MAGNETICS
AERTECH INDUSTRIES
AGFA
AIM
AIRFORCE HANSCOMB FIELD
ALCOA
ALIOTH ASSOCIATES
ALLEGHENY LUDLUM
ALLIED CORPORATION
ALPHA DATA
AMAX SPECIALTY METALS
AMCODYNE
AMF TUBOSCOPE
AMPEX
APCI
APOLLO MAGNETICS
APPLIED DATA
APPLIED MAGNETICS
ARMCO
ARMY
ARNOLD ENGINEERING
AT&T
ATHANA
BAKER ELECTRONICS
BASIC FOUR
BBM CORPORATION
BELL LABS
BENTLEY NEVADA
BETHLEHEM STEEL
BLACK & DECKER
BODINE ELECTRIC
BOEING
BOSE
BRIGGS & STRATTON
BROWN DISK MANUFACTURING
BUREAU PRODUCTS
BURNS RESEARCH
BURROUGHS
CABOT
CALTECH
CAP MAGNETIC PRODUCTS
CARLTON CONSULTING
CARMEL CHEMICALS
CARNEGIE MELLON UNIVERSITY
CARTECH
CENTURY DATA
CERAMIC MAGNETICS
CERTEL INCORPORATED
CIPHER DATA PRODUCTS
CMC TECHNOLOGY
COLLEGE OF WILLIAM & MARY
COLT INDUSTRIES
COMPUTER PERIPHERALS
COMPUTER POWER
CONRAIL CORPORATION
CONSULTANT
CONTROL DATA
CORCOM INCORPORATED
CORNING
COLORADO STATE UNIVERSITY
CURRY ENGINEERING
CUTLER-HAMMER
CYBERNEX
D. M. STEWARD
DATA ELECTRONICS
DATA GENERAL
DATA MAGNETICS
DATA PRODUCTS
DATAFLUX
DEC
DEL ELECTRONICS
DELCO REMY
DENNISON
DEPOSITION TECHNOLOGY
DESOTO INCORPORATED
DIAMOND RESEARCH
DISCO VISION
DISCOVER TECHNOLOGY
DISCTRON
DISK TECHNOLOGY
DMA SYSTEMS
DOFASCO
DOW CHEMICAL
DUMONT WORLD
DUPONT
DYMEK CORP
DYSAN
ECHO SCIENCE
EG&G
EIKON

ELECTRO ENGINEERING WORKS
ELECTROCUBE
ELECTRON ENERGY CORPORATION
EMERSON MOTOR
EMS DEVELOPMENT CORPORATION
ERADCOM
ERIEZ MANUFACTURING
ESPEY MFG. AND ELECTRONICS
F.W. BELL
FAIRCHILD WESTON SYSTEMS
FERROXCUBE
FIELD EFFECTS INCORPORATED
FLORIDA INSTITUTE OF TECHNOLOGY
FOOTHILL ELECTRONICS
FOXBORO
FRANTZ LABORATORIES
FRONTIER TIMBER COMPANY
GBS ENTERPRISES
GENERAL ELECTRIC
GEORGE ASSOCIATES
GRAHAM MAGNETICS
GT&R PLASTIC
GTE
GULTON INDUSTRIES
GEORGE WASHINGTON UNIVERSITY
GEORGIA TECH
HAMILTON DIGITAL CONTROLS
HARDER COMPANY
HERCULES
HEWLETT-PACKARD
HITACHI MAGNETICS
HOEGANNES
HONEYWELL
HOOSIER MAGNETICS
HUGHES AIRCRAFT
HURNEY MAGNETICS
IAP RESEARCH
IBIS SYSTEMS
IBM
IG TECHNOLOGIES
IGC
INFOMAG
INLAND STEEL
INTERNATIONAL JENSEN
INTERNATIONAL SCIENTIFIC
INTERNATIONAL SIGNAL AND CONTROL
IOMEGA
IOWA STATE UNIVERSITY
IRWIN INTERNATIONAL
ITT NORTH MICROSYSTEMS
KENNEDY COMPANY
KILLMORGEN CORPORATION
KJS ASSOCIATES
KOMAG
KROKER ENGINEERING & DEVELOPMENT
LASL
LDJ ELECTRONICS
LOCKHEED
MAGNETIC MEASUREMENTS CORPORATION
MAGNETIC PERIPHERALS
MAG-MEDIA
MAGNEBIT
MAGNET MANUFACTURING
MAGNETIC SYSTEMS
MAGNETICO
MAGNETICS INCORPORATED
MAGNETOGRAPH
MAGNEX
MARQUETTE UNIVERSITY
MARKO METALS
MATHEMATICAL SCIENCE
MAXELL
MAXWELL LABORATORIES
MEDIA INCORPORATED
MEDIA SYSTEMS TECHNOLOGY
MEDIA TECHNOLOGY
MEDIA TEST SPECIALISTS
MEMOREX
MEMORY CONTROL TECHNOLOGY
MICHIGAN STATE UNIVERSITY
MICROPOLIS
MIT
MOBIL OIL
MOLYCORP
MOTOROLA
MUSHIELD
NARCO AVIONICS
NASA GODDARD
NASHUA CORPORATION
NATIONAL MICRONETICS
NATIONAL SEMICONDUCTOR
NATIONAL CORPORATION
NATIONAL MICRONETICS
NAVY NRL
NAVY SURFACE WEAPONS CENTER
NATIONAL BUREAU OF STANDARDS
NEVADA STATE UNIVERSITY
NEW ENGLAND NUCLEAR
NICOLET
NOGO CORPORATION
NORTH CAROLINA STATE UNIVERSITY
NORTHERN TELECOM
NORTRONICS
NATIONAL SECURITY AGENCY
NYU
O. S. WALKER
OKLAHOMA STATE UNIVERSITY
OMI INTERNATIONAL

OPTICAL INDUSTRIES
OPTICAL PERIPHERALS LABORATORY
OTTAWA CHEMICAL
P&R MOTORS
PA INCORPORATED
PENN STATE
PERFECTDATA
PERKIN-ELMER
PERMABYTE MAGNETICS
PERMANENT MAGNET COMPANY
PERTEC COMPUTER
PFIZER
PIONEER MAGNETICS
POLAROID
POLYMER CORPORATION
POTTER INSTRUMENTS
PRATT & WHITNEY
PRECISION COIL PROCESSING
PRIAM
PROCTOR COMPANY
Q.V.S. INCORPORATED
QUANTEX
R. B. ANNIS COMPANY
RAWSON-LUSH
RAYMOND ENGINEERING
RAYTHEON
RCA
REMEX
REPUBLIC STEEL
RESEARCH ASSOCIATES
RESONEX CORPORATION
ACTIVE RETIRED
RFL INDUSTRIES
ROCKWELL
ROGERS CORPORATION
S. G. FRANTZ COMPANY
SALA MAGNETICS
SANDIA LABORATORIES
SCHONSTEDT INSTRUMENT COMPANY
SCOT INCORPORATED
SEAGATE TECHNOLOGY
SEIMENS-ALLIS
SENSORMATIC
SHUGART
SIMMONDS PRECISION
SINGER COMPANY
SOUTHWALL
SPANG INDUSTRIES
SPARC X3B8 LIAISON
SPERRY
SPIN PHYSICS
STANFORD UNIVERSITY
STAR HILL
STORAGE TECHNOLOGY
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SYNCOM
TANDON CORP
TANDY
TDK ELECTRONICS
TECHNITROL
THOMAS & SKINNER
TIBBETTS INDUSTRIES
TRANSMAG CONSULTING
TRI
TRW-VIDAR
TYLER POWER
UNIV. OF CALIFORNIA AT IRVINE
UNIVERSITY OF FLORIDA
UNION CARBIDE
UNIVERSITY OF DAYTON
UNIVERSITY OF MINNESOTA
UNIVERSITY OF PENNSYLVANIA
VA
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The report summarizes the analysis of responses to a survey of industrial needs for magnetic services and research.

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