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EDUCATIONAL OPPORTUNITIES FOR NDE AT UNIVERSITIES

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We begin with the premise that, unfortunately, there exists a gap between the actual and perceived needs of industry for NDE, and the research and education in NDE at the university level. We would hope to help bridge this gap by appropriate communications between the two sectors, which is one of the reasons for these sessions today. Part of the information of importance to industry is what opportunities currently exist at the university level for educating engineers who will be prepared to make significant contributions to advances in NDE technology. Or, if such university programs do not now exist, what is being planned to introduce and develop such programs.

The American Society for Nondestructive Testing (ASNT) publishes yearly the Redi Reference Guide as one of the issues of its journal, Materials Evaluation. Among much other information, the Redi Reference Guide includes a list of those institutions which offer any sort of educational programs in what it calls nondestructive testing. These institutions include high schools, vocational-technical schools, junior colleges, senior colleges and military-related schools. It also lists short-term programs offered by industrial or professional societies. It is fairly clear from the brief descriptions of the programs offered by all of these, with the possible exception of some of the senior colleges, that what is being offered is technician training, and not a full-fledged engineering degree, in the accepted sense, with emphasis on NDE.

There are 26 so-called senior colleges listed. Of these 26, only 17 can be considered to be universities with complete engineering curricula. Of these 17, however, six clearly identify NDT as optional within an engineering technology program, one lists a single one-semester elective course, and all but one of the rest define NDT courses as supplemental—i.e., optional—to other engineering programs either unspecified or specifically identified. Only one specifically refers to NDE, as contrasted to NDT, and that at the Master's degree level. It should be noted, however, that the use of the name NDT does not in itself imply technician level training rather than engineering level education.

It was felt that it was necessary to attempt to flesh out the brief information contained in the ASNT publication. Consequently, I wrote to 13 of what may be called senior universities which had shown some evidence of work in NDE, either through advertised programs, or because faculty from these universities had presented research papers in NDE at recent technical meetings. Included in this list
of 13 are most of the senior engineering colleges identified in the Redi Reference Guide. There is no assumption that the list covers all universities with a possible claim to programs in NDE. But the list of 14 (including Iowa State University) is a representative geographic cross section. I wrote to specific individuals at each of these universities. In most cases these individuals answered personally; in some cases my request was turned over to another individual for reply. I did receive information from 12 of these schools. I later learned that the individual to whom I wrote at one of those schools not responding had left the university. The other one of those not responding is, however, listed in the Redi Reference Guide, where NDT is described as supplemental to other programs in a Mechanics and Materials Science Department. Of the 12 who did respond, two flatly stated that they are not now offering any courses in NDE. These are the University of Michigan and Northwestern University. The remaining 10 then are as follows:

Colorado State University, Fort Collins, Colorado
University of Denver, Denver, Colorado
University of Houston, Houston, Texas
Ohio State University, Columbus, Ohio
Pennsylvania State University, University Park, Pennsylvania
Stanford University, Stanford, California
University of Tennessee, Knoxville, Tennessee
Virginia Polytechnic Institute & State University, Blacksburg, Virginia
Texas A&M University, College Station, Texas
Iowa State University, Ames, Iowa

After referring to this meeting, what I requested from each individual was as quoted from my letter:

I have been asked to survey a selected list of universities to determine what courses, curricula or programs in NDE are now available or in the planning stage. You have been suggested as one who would be aware of what is being taught or proposed at your university.

I would very much appreciate receiving from you a brief description of any such courses or programs now being offered or proposed, either in your department or elsewhere in your university.

The following is a summary of the information received from each respondent.

**Colorado State University**

NDT (here called NDT) is concentrated in the Department of Electrical Engineering primarily through the efforts of Prof. William Lord. No courses are specifically identified as NDE. NDE emphasis in the EE curriculum is concentrated in senior projects. This summer Prof. Lord proposes to offer a senior/graduate level experimental course called Nondestructive Testing, which it is hoped will be the key course for an NDT option at the bachelor's level in EE NDT, and for an NDT emphasis at the Master's level. The content is described as follows:

The course is intended to provide an overview of state-of-the-art methods for detecting defects in critical metal components. Emphasis will be placed on the underlying physical principles of radiographic, electromagnetic and acoustic NDT methods and use of these principles in practical testing situations.

Prof. Lord has a group of graduate students working on sponsored projects related to electromagnetic NDT methods, in addition to the undergraduates working on NDT senior projects.
University of Denver

Correspondent was Prof. Steve Carpenter of the Department of Physics. Denver currently has no engineering program, although it has recently been authorized to establish an engineering program with B.S. degrees initially in mechanical and electrical engineering. There are no NDE courses offered. However, in conjunction with the Denver Research Institute, research is carried on in acoustic emission and NDE materials related research. Student involvement is on the graduate level, and any instruction is by seminar or independent study.

University of Houston

Correspondent was Prof. Kamel Salama, Department of Mechanical Engineering. There exists only one course identified specifically as NDE, which is listed in Mechanical Engineering and called Fundamentals of Nondestructive Testing. It is taught every year as a 3-credit hour course at the senior/graduate level; it includes five laboratory experiments. Basically, it is a survey of the classic NDE techniques, including dye penetrants, magnetic particles, eddy currents, ultrasonics and radiography. Brief mention is made of some of the more advanced NDE techniques.

At the graduate level students may take courses in electromagnetics, acoustics or physical acoustics.

Ohio State University

Ohio State has the most fully developed program in NDE education of those surveyed. The Redi Reference Guide describes "NDE as a required part of the welding Engineering B.S. program." The NDE program is directed by Dr. Laszlo Adler from the Department of Welding Engineering (Chairman: Prof. Karl Graff), and includes faculty from a number of different disciplines.

The undergraduate degree is a B.S. in Welding Engineering, which includes one senior/graduate level course called Nondestructive Evaluation (An Introductory Course), which is a survey course of basic NDE techniques; it does include a laboratory. There are three other courses at the graduate level: ultrasonic nondestructive evaluation (advanced ultrasonic NDE), electromagnetic nondestructive evaluation (advanced EC and EM methods), and advanced NDE methods (spectroscopy, optics, radiography, signal processing...).

The NDE program is a well defined, coordinated program of research and teaching; it apparently appears to emphasize graduate education and research. The undergraduate degree, as noted, is Welding Engineering, which must inherently include principles of structural and materials reliability. The literature received speaks of an NDE option at the B.S. level, although specific courses in the option, other than the one senior course previously noted, are not identified. In contrast, the M.S. program in NDE is well defined in terms of course work. There are plans to introduce additional NDE courses and enlarge the scope of the NDE program.

Pennsylvania State University

No specific courses now being taught. A senior/graduate level course is being proposed. This would be essentially an introductory survey course in NDE techniques, to be considered as an essential part of engineering analysis and design. It is proposed to be a course cross-listed in different disciplines, and possibly team taught. A principal push for the course is coming from the Department of Engineering Science and Mechanics (Chairman: R.P. McNitt).

Stanford University

Response from Prof. Gordon Kino, Electrical Engineering and Applied Physics. Stanford does not offer any courses specifically identified as NDE. NDE is almost
exclusively addressed at the Ph.D. research level, involving faculty from a number of different areas. Research is strongly interdisciplinary. Courses taken by the students are appropriate to their major fields, but do form the basis for eventual research in an NDE related area.

University of Tennessee

I can best describe what is being done at Tennessee by quoting from an article in Materials Evaluation (December 1981). The NDE program is part of the NDE Division of the University, under the direction of Prof. Bruce Dewey. The NDE Division is an interdisciplinary structure built around common interests in NDE research by faculty from various areas in the university. The quotation follows:

A structured NDE undergraduate program is offered in engineering science or in engineering physics...The undergraduate Engineering Science program is accredited and provides a broad general background in mechanics, thermodynamics, heat transfer, mathematics, computer science, humanities and social studies. The Engineering Physics program offers a similar background of courses; the senior year includes a general NDE course (offered annually with an enrollment of nearly 20), and specific courses in ultrasonics and eddy currents. Undergraduate NDE studies prepare students in the underlying sciences rather than in the operation of scientific equipment, and particular emphasis is placed on a well-rounded, technical education.

NDE graduate programs are built around ongoing research projects, with close working relationships with Oak Ridge.

Virginia Polytechnic Institute & State University

NDE is identified with the Materials Response Group of the Department of Engineering Science and Mechanics. The undergraduate curriculum is Engineering Science and Mechanics, which is not an atypical program. There are a number of elective hours available. For an emphasis in NDE, specific courses are suggested, only two of which are specifically identified as NDE--again an introductory survey course with an associated laboratory (not yet in place).

At the graduate level, the Master's degree is in Engineering Mechanics with one additional NDE-defined course now available (Nondestructive Research Testing) and three others proposed to be offered (Seminar in NDE of Materials, Advanced Applications of Ultrasonics, and NDE of Composite Materials).

Texas A & M University

Subsequent to the workshop at Orlando, information has been received on an NDE program at Texas A & M University, primarily in the Department of Mechanical Engineering. Two courses may be specifically identified as nondestructive testing/inspection/evaluation, one in Mechanical Engineering and one in the Engineering Technology program. Both of these are at the senior/graduate level and are basically survey courses of NDE/NDT techniques. Each has a laboratory portion, although the ET course offers more hands-on experience.

A Master of Engineering in Mechanical Engineering with specialization in nondestructive inspection is available. Only the previously noted courses are specifically identified as NDE (or NDT, NDI), although there exists the elective possibility of a one-on-one course in Advanced Topics in Nondestructive Inspection.

Research in NDE appears to be directed primarily to problems associated with the railroad industry; it has been funded by DOT and the railroad industry.
Iowa State University

Iowa State University falls into a pattern similar to Tennessee and VPI and Stanford University. There exists a structured, accredited undergraduate program, leading to the bachelor's degree in Engineering Science. The program is administered by the Department of Engineering Science and Mechanics. It contains a number of elective hours which allow the student the opportunity to specialize in different areas. One such area would be NDE. As with the other two programs, there is now in place a senior/graduate level course in NDE which is an introductory survey of the basic NDE techniques. A senior/graduate level seminar is offered yearly which focuses on specific state-of-the-art evaluation methods.

The basic structure of the programs at ISU, Tennessee, VPI, Penn State and SU is similar. It produces an engineer with a multidisciplinary background and with some familiarity with NDE in terms of concepts and accepted techniques. While differing in details, the composition of the four programs is sufficiently similar that a description of the one at ISU will give the flavor of all four.

Bachelor of Science in Engineering Science with Emphasis on Nondestructive Evaluation. This is an ABET accredited four-year baccalaureate program which requires six more semester credits than the standard ES degree. It uses only courses now existing in the university; others can be substituted or included as experience and need dictate. Those courses marked with an asterisk are beyond the basic curricular requirements and are included as part of the NDE emphasis.

<table>
<thead>
<tr>
<th>Topics</th>
<th>Semester Credits</th>
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<tbody>
<tr>
<td>2. PHYSICS &amp; CHEMISTRY: General Chemistry (with laboratory), Classical Physics, Modern Physics*</td>
<td>18</td>
</tr>
<tr>
<td>3. COMMUNICATIONS: Composition &amp; Reading, Technical Writing</td>
<td>9</td>
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<tr>
<td>4. SOCIAL-HUMANISTIC: Government, History, Economics, etc.</td>
<td>14</td>
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<td>5. ENGINEERING SCIENCES:</td>
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<td>A. SOLID MECHANICS: Statics, Dynamics, Strength of Materials, Mechanics Laboratory (testing machines, strain gages, brittle coatings, optical methods), Mechanical Behavior* (NS&amp;E) (Elasticity, plasticity, fracture, fatigue, metal processing technology)</td>
<td>13</td>
</tr>
<tr>
<td>B. FLUID MECHANICS, THERMODYNAMICS (ME)</td>
<td>7</td>
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<tr>
<td>C. MATERIALS SCIENCE (MS&amp;E): Engineering Materials (with laboratory), Nuclear Materials &amp; Radiation Effects*</td>
<td>7</td>
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<td>D. RATE AND TRANSFER PROCESSES (ME)</td>
<td>3</td>
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<tr>
<td>E. ELECTRICAL SCIENCES (EE): Circuits, Electronics, Instruments &amp; Systems (with laboratories)</td>
<td>9</td>
</tr>
<tr>
<td>6. ANALYSIS, DESIGN, EXPERIMENTATION: Freshman, Sophomore, Junior and Senior years (with studios/laboratories)</td>
<td>15</td>
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</table>
7. OTHERS/SPECIALTIES: Engineering Programs, Energy Sources
& Utilization, Nondestructive Evaluation* (MS&E-ES/M)
(with laboratory), Measurements & Instrumentation* (ME)
(with laboratory), Acoustics,* Vibrations, Library,
Freshman and Senior Seminars

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<tr>
<th>Topics</th>
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<td>18.5</td>
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<td>Total</td>
<td>139.5</td>
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To the above should be added that a full-fledged undergraduate laboratory course in NDE methods is being developed. The necessary equipment is on order now. Two new courses are being proposed, one at the senior/graduate level and one at the graduate level. These will be described in more detail in a later paper.

There is an intensive and extensive research program in place in various areas of the university: in Engineering Science and Mechanics, in Materials Science and Engineering, the Basic Energy Sciences program of DOE, and various major research contracts (AF/DARPA, Navy/DARPA, ONR, etc.). Research in NDE enters into the graduate program at both the Master's and Ph.D. levels.

In summary, what we can conclude from the preceding is that there does not now exist a structured program at the undergraduate level leading to an engineering degree with a major emphasis in NDE. The closest is the Welding Engineering program at Ohio State. But there do exist programs which produce engineers with strong, broadly based, scientific and engineering academic experience, and with some familiarity with the basic concept of NDE and current NDE practices. Furthermore, these programs are making definite efforts to increase the amount of material available for an NDE emphasis within the framework of a structured engineering program. However, we do not see any attempt to define an engineering degree called Bachelor of Science in Nondestructive Evaluation.

Research and education at the graduate level in NDE is flourishing, though most of the support appears to come from the academic and government sectors rather than from industry. The basic directions of the educational programs appear to be those imposed by the perceptions of the academic community, with not much input from the industrial community (with a few exceptions). This is not meant as a criticism, but as an observation. The point of these sessions today is to increase the opportunity for communication between the university and industry, and to encourage input from industry in helping shape the educational programs.

DISCUSSION

Q: If I understand you correctly, you're saying that you do not see that NDE can be a recognized discipline in the academic community.

A: No. If I gave that impression, I apologize. That is not what I meant to say. What I tried to say was that I don't see that there is an undergraduate curriculum now leading to a Bachelor of Science in Engineering with a major emphasis in NDE. I think there are efforts being made to change the emphasis. But what I do see is that the emphasis will still be on a structured engineering program which will be a bachelor of science in electrical engineering, a bachelor of science in mechanical engineering, a bachelor of engineering science, with more emphasis on coursework in the NDE area. In keeping with the previous paper, I don't think that we're going to be able to graduate someone who is going to be able to go out on the floor and use all of the necessary techniques and skills immediately out of college.

Q: Why is it that a lot of the activity at a university, as you have pointed out, for NDE is relegated to Master's or Ph.D. levels?
A: I think part of the reason is the necessary structuring of the basic undergraduate curriculum which does not allow, at the moment, room for enough information to be given to the students in terms of coursework that they can do anything other than become familiar with the language of NDE by the time they get their bachelor's degree. I think it takes more education than they can obtain at the bachelor's level.

Q: What brings the graduate students to work in the area of NDE?

A: The reputation of the people involved, money to help support them, the particular interest a student may have for a particular type of problem that would be brought to his attention.

Q: My perception is that NDE crosses so many boundaries of the conventional disciplines that it brings some of the greatest challenges that exist in the universities today, once you get out of the purist side of engineering or academia. What I mean by that is that many physicists, mechanical engineers and electrical engineers are going into application of their expertise to NDE-type problems. Is it the fact that NDE now has problems that are available that need to be solved? Is that what is bringing them to it, because it's challenging?

A: Oh yes, very much so. But I do think that the challenge will be presented by the actions of the faculty members involved and not because a student, after having taken an introductory survey course in NDE at the undergraduate level, is going to go to graduate school and say, "I want to work in NDE." You're going to have to find the people at the university who are interested in working in the NDE program. The usual procedure is for the student to go where the professors are, rather than where the problems are, or where the money is, one or the other.

Q: So what we need to do is to educate more professors in bringing more graduate students into this kind of program?

A: I agree entirely.

Q: What you've said about that relates back to what Bill Kitson was saying about so many of the people, experts in the field, being in industry. Is it possible for you to pull people from industry in to handle parts of your courses in the universities?

A: That would be a development to be fervently sought and I don't know whether it would be possible or not. I know of no university that would object. In fact, they would jump at the chance to have experts from industry come in and work very closely with their academic programs, if they could be shaken loose from industry. There may be a problem of comparable salaries which would have to be faced. These details would have to be worked out. If industry is really concerned about seeing that we graduate the right sorts of people, then I think some accommodation has to be made in which possibly part of a salary would be paid by industry, as part of its long-range development plans.

Q: I just wanted to add a cheery note here. We've had some success by having support from industry in our area. The General Electric Company has provided some material, $50,000 worth. It turns out that with a total of $100,000 you can set up a laboratory. We've done that. But the point I wanted to make is that if you combine this with something else, you have another drawing card. For example, a QA program that we have incorporates some NDE and that's been attractive to students. We now have a center for manufacturing with an academic program where we introduce some of the cutting edge in that process--robotics, remote control machines, and so on--and at the end of that sequence of things we have the NDE plugged in. This is also a way to get into the business, attracting students and funds both.
Q: I conclude from your information that there are very few universities percentage-wise across the whole country emphasizing the subject. In some sense, if we believe this job must be done, people who are like you ought to act as missionaries. My question to you is that your speech did not strike me as indicating that you are very enthusiastic about this whole program.

A: You're incorrect. I'm very enthusiastic about it. I'm sorry that I had to paint such a bleak picture of what is going on now. Perhaps I didn't give enough of a hopeful note of what we hope to be able to do in the near future and what efforts are being made. I can most specifically speak for what we are trying to do at Iowa State University in terms of the introduction of new courses, the acquisition of equipment for laboratories, and the development of research programs that will bring in more students. We at Iowa State suffer from not being in an industrial area, geographically speaking. We have to reach out and get contact with industry much more forcefully than some people in some of the bigger communities. But we're still trying. I think it's hopeful.