A DEMOGRAPHIC PROFILE OF NONDESTRUCTIVE INSPECTION AND TESTING (NDI/NDT) PERSONNEL: A PRELIMINARY REPORT

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Background: Aircraft maintenance relies on nondestructive inspection and testing (NDI/NDT) to ensure aviation safety. The visual capabilities of workers are important elements to efficient inspections. Because worker demographic characteristics are important predictors of many visual measures, a survey within aircraft maintenance facilities was undertaken. **Methods:** Data from nine facilities were analyzed to determine a profile of the NDI/NDT workforce, the type and frequency of procedures performed, and vision screening practices. **Results:** Of 889 NDI/NDT personnel, 99% were male. Job classifications included 52% Visual Inspectors, 36% Visual-NDI/NDT personnel, and 12% NDI/NDT Specialists. Median age was 45 years, and ethnic diversity included 73% Caucasians, 13% Asian-, 7% Hispanic-, 6% African-Americans, and 1% others. Eddy-current inspection was performed most often, while radiographic inspection was performed least. **Conclusions:** Preliminary analysis suggests that the visual capabilities and ophthalmic conditions related to males over 40 years of age should be given special consideration in the implementation of a vision-screening program.

INTRODUCTION

Continuous maintenance of aircraft and aircraft components using both visual inspection and nondestructive inspection and testing (NDI/NDT) procedures is crucial for maintaining a high level of aviation safety. Visual inspectors are highly qualified individuals who use their vision, with or without optical aids, to make judgments about the condition of aircraft and aircraft components being inspected. NDI/NDT specialists are trained to perform technical procedures and to use sophisticated imaging devices and equipment necessary for conducting a variety of procedures. Visual inspectors and NDI/NDT specialists are often considered to be separate groups. However, some maintenance facilities do not formally distinguish between these groups since, in practice, there is considerable overlap in the tasks they perform and the expertise that is required. The major difference between these workers is that visual inspectors normally inspect the assembled (or partially assembled) aircraft, while NDI/NDT specialists tend to focus on the aircraft's individual components. Regardless of job classification, optimal visual performance specific to the task at hand is perhaps the most important physiological attribute these individuals possess to ensure they perform their job responsibilities well. (NOTE: Except when it is appropriate to do otherwise, this document will refer to visual inspectors and NDI/NDT specialists collectively as NDI/NDT personnel.)

Although the Air Transport Association (ATA) Specification 105 (2002) recommends a minimum visual performance standard, there is currently no federal policy to ensure that persons performing aircraft maintenance and inspection tasks meet a specific vision requirement. Various industry programs have adopted some form of the ATA Specification 105 recommended vision standard for NDI/NDT personnel. However, the vision requirements set forth in these programs are not standardized throughout the industry, nor are they based on any known visual job-task analysis. An assessment of the visual performance demands placed on NDI/NDT personnel is needed to develop a job-relevant vision standard.

In two important ways, vision standards differ from other human factors as it relates to job success. First, visual performance can be measured quickly, comprehensively, and dependably. Second, when vision performance falls below a desirable level, it can be improved in a majority of cases and at relatively low costs. About 50% of adults in the United States have difficulty seeing distant objects clearly, and about 60% have difficulty seeing up close when no corrective lenses are worn. Research (Kleinstein, 1993) with subjects using their usual refractive corrections has indicated that the prevalence of impaired distant and

near vision can be as high as 30% and 40%, respectively. These numbers can be substantially reduced when best-corrected visual acuity (BCVA) is provided. One study (Zerbe, 1958) involving over 500 patients (20 to 60 years of age) found that only 6% could not be improved to 20/20 visual acuity with BCVA and fewer than 1% were incapable of 20/30 visual acuity. Therefore, should the presently employed vision standards need to be made more stringent, there should be no appreciable reduction in the current NDI/NDT workforce. An appropriate task-related vision standard would compel workers to obtain proper refractive correction designed specifically for their job responsibilities. Job opportunities may be more numerous for the few workers unable to achieve or maintain a high level of BCVA should research find that a lower level of visual performance is adequate for some inspection activities.

Since a substantial percentage of the general population has impaired vision with their present corrections, a similar percentage of the NDI/NDT workforce may possess less than optimal vision. Kleinstein (1993) found that poor vision reduced the performance and productivity of workers and increased the risk of mistakes or accidents. While the medical costs of workplace injuries due to some vision-related accidents are reported by government agencies and insurance companies, the cost associated with untreated vision disorders in NDI/NDT personnel is not easily assessed. Workplace injuries aside, vision problems present in these individuals could lead to flawed inspections that result in aircraft accidents, injuries, and/or fatalities, as well as financial losses from liability litigation and poor public relations. For example, the National Safety Transportation Board (NTSB) has cited the failure to identify visually detectable corrosion and cracks as the probable cause of the following aviation accidents:

- Delta Airlines, Flight 1288; July 6, 1996 (NTSB Report AAR/98/01) — A crack with a total surface length of 1.36 inch in the front compressor hub of a Pratt & Whitney JT8D-219 engine was not detected during visual and fluorescent penetrant inspections, which resulted in an uncontained engine failure during takeoff.

- United Airlines, Flight 232; July 19, 1989 (NTSB Report AAR/90/06) — A crack with a total surface length of 0.498 inch in the stage-1 fan disk of the No. 2 CF6-6 engine was not detected during visual and fluorescent penetrant inspections. The NTSB determined that at least two inspections were performed after the crack had reached a detectable length.

- Aloha Airlines, Flight 243; April 28, 1988 (NTSB Report AAR-89/03) — The NTSB determined that the cause of this accident was the failure of the Aloha Airlines' maintenance program to detect the presence of significant disbanding and fatigue damage, which ultimately led to the failure of lap joint at stringer 10L. A passenger reported seeing cracks near the door while boarding the aircraft.

A Federal Aviation Administration (FAA) Advisory Circular (AC 43-204), entitled "Visual Inspection for Aircraft" (1997), states that over 80% of the inspections on large transport aircraft are visual inspections. This percentage is even greater for small transport and general aviation aircraft. FAA regulators, including the Aircraft Maintenance Division (AFS-300) and the Aircraft Maintenance Technical Committee Representative Group, have recently expressed concern that the current vision standards adopted by industry may not be adequate for all tasks performed by NDI/NDT personnel, suggesting that more appropriate task-based vision standards should be developed.

This report provides preliminary data that describe the NDI/NDT workforce and procedures performed by three major air carriers (nine facilities) in the United States. Once complete, information provided in this study will be used to help establish appropriate vision standards based on the visual demands of NDI/NDT procedures.

METHODS

A survey is being conducted that includes gathering data on the type and frequency of NDI/NDT procedures performed at major aircraft maintenance and manufacturing facilities in the United States. Demographic and procedural information was gathered by soliciting responses to a survey questionnaire submitted to supervisory personnel at three major U.S. air carriers serviced by nine separate maintenance facilities (Note: For the sake of anonymity, the three airlines in this survey were assigned the designations Airline A, Airline B, and Airline C). The requested data includes the number, classification, and other pertinent information necessary to describe the NDI/NDT personnel populations at these facilities, the type and frequency of NDI/NDT procedures performed, and the current vision screening practices these facilities employ.

RESULTS

FIGURE 1: WORKFORCE DISTRIBUTION

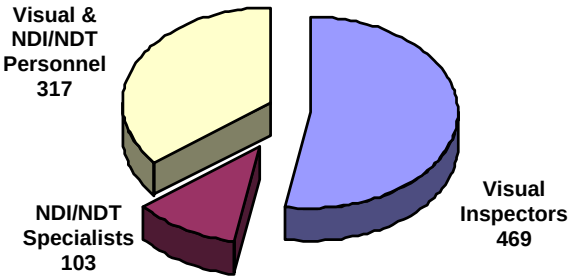

Figure 1 shows the population frequency, by job classification, for the 889 NDI/NDT personnel surveyed. The job classification percentages represented are 52%, 12%, and 36% for Visual Inspectors (n = 469), NDI/NDT Specialists (n = 103), and Visual-NDI/NDT personnel (n = 317), respectively.

TABLE 1: WORKFORCE FREQUENCY & AGE

Airline	Facility	Employees	Age Range	Median Age
A	1	304	35 – 65	47
B	2	96	30 – 62	37
	3	135	39 – 67	45
	4	185	32 – 76	53
C	5	42	30 – 64	45
	6	13	40 – 70	62
	7	43	25 – 64	45
	8	58	22 – 65	35
	9	13	35 – 62	45
Total		**889**	**22 – 76**	**45**

Table 1 provides the number of employees, minimum and maximum ages, and median age of NDI/NDT personnel by facility. The median age for the survey population was 45, with an age range of 22 to 76 years.

FIGURE 2: WORKFORCE DIVERSITY

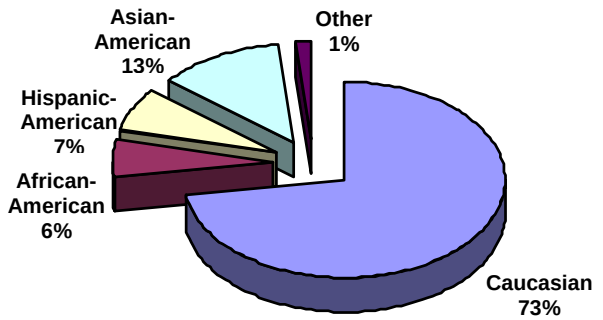

Figure 2 illustrates the percentage of NDI/NDT personnel surveyed at all facilities by cultural ethnicity. The percentages represented include 73% Caucasians (n = 645), 13% Asian- (n = 113), 7% Hispanic- (n = 62), 6% African-Americans (n = 55) and 1% other (n = 14) ethnic cultures present in the survey population. In addition, males comprised 99% (n = 880) of the NDI/NDT employee population surveyed.

TABLE 2: NDI/NDT PROCEDURE RANKING

Procedures	Rank
Eddy Current	1
Fluorescent Penetrant	2
Borescope	3
Ultrasonic	4
Magnetic Particle	5
Radiographic	6

Table 2 provides the cumulative ranking of the NDI/NDT procedures (1 = most often performed; 6 = least often performed) identified in this survey. Four facilities provided rankings, which were weighted by the proportion of personnel who performed these procedures and summed to provide a cumulative rank for each procedure. The results indicate that personnel at these facilities most often performed eddy-current inspection, while radiographic inspection was least often performed.

Vision standards employed by each of the three airlines surveyed (Airline A, 1994; Airline B, 2000; Airline C, 2002) were at least as stringent as the ATA Specification 105 recommendations.

DISCUSSION

The population demographic data collected to date for NDI/NDT personnel describes a relatively homogenous collection of individuals. The majority of the workforce is male (99% vs. 55% in the US: Note: US statistics are based on data obtained from the Bureau of Labor Statistics, http://www.bls.gov, June 2003, for employed males ≥ 20 years of age) and Caucasian (73%), with a median age of 45 years (vs. 41 years in the US: M. Di Natale, Bureau of Labor Statistics, written communication, June 2003). NDI/NDT inspectors, in this preliminary study, are older than their colleagues who perform only visual inspection duties. This may be due to seniority preferences for NDI/NDT positions in unionized facilities.

Conducting NDI/NDT procedures tends to be a more sedentary activity, often performed in a controlled environment. Conversely, the duties of a visual inspector often requires more physical prowess, calling for a considerable amount of standing, walking, climbing, bending, and crawling into tight spaces. Visual inspections are usually performed in a hangar environment or in the ramp area. The median age and age range of visual inspectors at different sites varied widely and may depend on a number of factors, including seniority preference for particular jobs, geographical location, and when the facility was built and staffed. For example, at older facilities where unions are prevalent, senior employees may request and be granted more desirable positions and work schedules. At facilities established more recently, employees are generally younger, and seniority may have less of an impact on staff positions.

Differences between visual inspector and NDI/NDT specialist operations vary according to the policies of the particular maintenance facility and/or airline. In some aircraft maintenance facilities surveyed, NDI/NDT and visual inspection activities operate almost independently. While in other facilities, both NDI/NDT and visual inspection personnel are combined into a single department under a common administrative staff. In these facilities, NDI/NDT personnel may do visual inspections, but not all visual inspectors are qualified to perform NDI/NDT procedures. In other words, specific job responsibilities are more a function of the individual's training and experience, rather than his/her specific employee classification.

There are few females employees (about 1%) in the NDI/NDT personnel population. The lack of females in the inspection population is probably because many candidates for NDI/NDT positions come from the ranks of those who started out as mechanics or other maintenance-related positions at these facilities. Traditionally, these occupations have been male dominated, which appears to explain the shortage of female NDI/NDT personnel found in this survey.

The NDI/NDT population appears racially diverse as indicated by Figure 2. While, in the facilities surveyed to date, the majority of the workforce is Caucasian (73% vs. 72.7% in the US), Asian (13% vs. 3.8% in the US), and Hispanic (7% vs. 12.4% in the US) employees represent substantial percentages, followed closely by African-Americans (6% vs. 8% in the US). To some extent, the differences in ethnic diversity for individual facilities appear related to the ethnic diversity of the general population where the facility is located. For example, in the California facilities surveyed, there are considerably more Asians employed as NDI/NDT personnel then there are in facilities surveyed that are located in areas where this ethnic group makes up a smaller percentage of the general population. According to the US Census Bureau's, Annual Demographic Supplement to the March 2002 Current Population Survey (2003), 51% of the Asian population in the US live in western states compared to 19% for non-Hispanic whites.

The most frequently performed NDI/NDT procedure is eddy-current inspection, and the least often performed procedure is radiographic inspection in the facilities surveyed to date. As indicated in Table 2, fluorescent penetrant, borescope, ultrasonic, and magnetic particle inspections were ranked second, third, fourth, and fifth, respectively, in frequency of performance at these facilities. However, individual facilities may not follow this ranking schedule if they specialize in the maintenance of a specific aircraft component or system. For example, survey responses indicated that, while eddy-current inspections were most prevalent at facilities that perform primarily airframe maintenance, the most frequent NDI/NDT procedure performed in power-plant (engine) maintenance facilities was fluorescent penetrant inspection. Dissimilarities in the procedures performed at different facilities may complicate development of uniform vision standards. For example, the visual demands of eddy-current inspections, which require reading relatively large displays, are less than those

necessary to detect tiny cracks when performing fluorescent penetrant inspections.

Vision testing procedures differed between the three airlines surveyed, suggesting that a more consistent procedural methodology should be developed. Additional research is ongoing to identify the vision requirements associated with the most visually demanding tasks performed by these workers. Once task-based visual performance requirements are properly assessed, appropriate vision standards and screening procedures can be developed.

CONCLUSIONS

Preliminary analysis suggests that employee job classification may be less of an indicator of visual performance requirements than the actual NDI/NDT inspection procedures being performed by these individuals. In addition, since the median age of the subject population is greater than 40 years of age, the combination of presbyopia and vision loss normally associated with age-related ophthalmic conditions should be a consideration in the development and implementation of a vision-screening program. Given that the population sample was made up of predominately male Caucasians, gender differences and ethnicity may need to be considered to a lesser extent when evaluating the vision performance characteristics of the current NDI/NDT personnel population. Special focus on the tasks necessary to competently execute the most visually demanding inspection procedures appears warranted. Once complete, this research will help determine the appropriate vision standards and screening procedures for initial qualification and re-qualification of personnel responsible for performing visual and NDI/NDT inspection of aircraft and aircraft components. Technical and advisory documents identifying vision testing equipment, procedural requirements, and preferred refractive corrections that may be advantageous to those performing specific job tasks will be additional benefits of this research.

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