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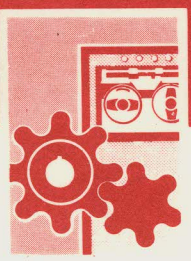

TECHNICAL REPORT

VIBRATION WHITE FINGER DISEASE in U.S. WORKERS USING PNEUMATIC CHIPPING and GRINDING HAND TOOLS

I: EPIDEMIOLOGY

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Centers for Disease Control
National Institute for Occupational Safety and Health

VIBRATION WHITE FINGER DISEASE IN U.S. WORKERS USING PNEUMATIC CHIPPING AND GRINDING HAND TOOLS
I: Epidemiology

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U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
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FOREWARD

From the onset, it was obvious that this project would require a multivolume report. Each volume would represent a discrete effort, complete in itself, without regard to other areas of the project (such as epidemiology or engineering). All the detailed results of a given project area would be contained in a volume of the project report, since we simultaneously attempted to meet the specific needs of engineers, physicians, physiologists, etc. We recognized that a separate publication bringing together the salient findings of all areas of this large study would also be necessary.

Volume I (epidemiology) and Volume II (engineering) represent a straightforward presentation of the study results. In Volume I, as well as Volume II, we have chosen not to discuss, interpret, or speculate on various aspects of the results. These discussions will be given in a separate, all-encompassing publication that combines the results of all areas of the project. By taking this approach, we are able to meet the needs of those readers interested in detailed findings as well as those readers mainly concerned with the conclusions drawn from all aspects of the study.

D. Wasserman
Project Director

ABSTRACT

A multidisciplinary study of 385 workers at two foundries and a shipyard was performed to determine the health effects of using pneumatic chipping and grinding tools on the job. This report presents the analyses of the questionnaire and medical examination data. Occupational histories were used to define exposure groups, and medical data were used to identify workers with confounding medical conditions. The exposed group, without confounding medical conditions, comprised 53% of the total study population and the medically selected, control group comprised 16%.

For the exposed group, the prevalence of vibration-induced white finger (VWF) (stages 01, 02, and 03) was 47% in the foundries and 19% in the shipyard. The prevalence of neurologic stages (OT (intermittent tingling), ON (intermittent numbness), and TN (intermittent tingling and numbness)) was 36% in the foundries and 45% in the shipyard. None of the workers in the control group had Raynaud's Phenomenon (those with confounding medical conditions were excluded). Graphic representation of the latencies of the three primary VWF symptoms of tingling, numbness, and blanching showed the median to be a more meaningful measure of VWF latencies. The median latencies of blanching were 1.4 years in the foundries, and 16.5 years in the shipyard. The median latencies of numbness were 0.8 year in the foundries and 9.5 years in the shipyard, while for tingling the median latencies were 0.6 year and 4.2 years, respectively.

In addition to VWF prevalence and latency results, the symptomatology of VWF was examined in depth along with the relation of VWF symptoms to social and hobby impairment indicators. An association was found between exposure variables, such as years on jobs using a chipping hammer and current job title, and the severity of VWF. Occurence of digit conditions, recorded during medical examinations, were analyzed for their relation to VWF severity and years of vibration exposure. The ability of three sensory tests to distinguish the stages of VWF is also presented.

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* The report contained herein represents only one portion of a large multi-disciplined vibration study. This report is complete in itself, however, the reader is advised to consult the other volumes comprising the entire study effort in order to gain a complete understanding of the scope of the project.

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INTRODUCTION

HISTORICAL BACKGROUND

In 1861, Dr. Maurice Raynaud wrote an M.D. thesis entitled "Local Asphyxia and Symmetrical Gangrene of the Extremeties" (1). This thesis included the first description of "a condition, a local syncope where persons, who are ordinarily females, see under the least stimulus one or more fingers becoming white and cold all at once. The determining cause is often the impression of cold. The cutaneous sensibility also becomes blunted and then annihilated." This clinical condition of "white finger" or "dead hand," which affects about 5 to 8% of the general population, has now passed into the terminology of clinical medicine as Primary Raynaud's Disease. The blanching attacks, usually affecting the fingers symmetrically, are relatively minor in the early stages of the disease. A small proportion (1% or less) may, however, become progressively more severe and, over a period of years, lead to blue cold fingers, wherein the skin becomes atrophic, later ulcerated, and finally gangrenous.

By the end of the 19th century, other conditions giving rise to Raynaud's Disease were recognized, particularly the association of vibratory tools with intermittent attacks of cold-induced pallor. Loriga (2) first described "vascular spasm," or white finger, in the hands of miners using pneumatic tools. Hamilton (3) studied miners using drills in the limestone quarries of Indiana and described "spastic anaemia of the hands." Researchers in the 1930s, showed that white finger syndrome was on the increase, as reported by Seyring (4), who studied fettlers in iron foundries; by Hunt (5), who studied riveters using pneumatic tools; and by Telford et al. (6), who described white fingers in men working with electrically driven high-speed rotating tools in a warm environment. In 1946 and 1949, Agate and Druett (7) examined 230 men who were grinding excess metal from small castings that were hand-held against 2-foot diameter grinding wheels. Of this total, 163 (70%) had a history of white fingers. At this time, the "white finger" condition appeared to be arising from the effects of prolonged hand exposure to vibration and the condition was referred to as "Raynaud's Phenomenon of Occupational Origin" and later as "Vibration-Induced White Finger" or VWF.

In 1962 and 1964, Ashe and his colleagues (8, 9) investigated a small group of hard-rock mine drillers from Saskatchewan, seven of whom were examined in the hospital. As part of the hospital investigations, arteriographies and biopsies of the digital arteries were performed. In the worst cases, extensive damage to the digital artery with narrowing of the lumen was demonstrated. These investigations illustrated that in severe cases extensive pathological damage to the arteries of the fingers could arise as a

result of prolonged exposure to vibration transferred from the tool to the hand.

From 1964 onward, an association appeared between Raynaud's phenomenon and chain saws. The chain saws were used extensively in the British forestry industry. By 1968-1969, when chain saw operators had accumulated 8 to 10 years of continuous use, complaints of VWF were reported in Britain. The vibration of the two-stroke internal combustion engine (reciprocating forces of the single cylinder two-stroke) is transmitted through the handles to the operators' hands causing white finger disease. Prevalence rates among workers in certain forests (where sawyers were working 5 to 6 hours per day, 5 days a week) were greater than 90%. Because of the increasing VWF prevalence rates and the deteriorating clinical state of the hands of chain saw operators, the British Forestry Commission in 1970 issued workers newly designed antivibration (A/V) saws.

By far the majority of VWF field surveys have investigated the gasoline-powered chain saw in a variety of countries (Australia (10), Canada (11), Czechoslovakia (12), Finland (13), Japan (14), New Zealand (15), Norway (16), Sweden (17), and the United Kindgom (18). Most other epidemiologic VWF surveys have investigated pneumatic tools, especially rock drills (19) different types of hand grinders (19-24) riveters (25) chipping hammers (3,19,22,23,25,26) and jack-leg type drills (14,27,28). Another pneumatic tool of importance is the jackhammer (also called road drill, concrete breaker, or road ripper). The use of jackhammers has not been studied in a population of workers because the user populations are very small and widely dispersed. Nevertheless, jackhammer use has been associated with symptoms of VWF (14,25) and a jackhammer operator had one of the severest cases of Raynaud's Phenomenon reported (29) (gangrene of the fingers) that could not be attributed to causes other than vibration.

Electric hand-held tools have received very little attention for a number of reasons. The vibration levels of electric tools are assumed to be lower because 1) electric motors are mechanically balanced systems (e.g., the gasoline-powered chain saw as opposed to the electric chain saw), 2) most electric tools are of the continuous rather than impact type, and 3) pneumatic tools can be operated more economically at higher torque and speed than electric tools. Electric tools are not used as often as pneumatics in mass production processes for economic reasons. Air supply is readily accessible in factories and since pneumatic tools do not have internal motors (as electric ones do), they are less expensive to make, buy, and maintain. Generally, electric tools are sporodically used on jobs for a short time, such as the use of electric drills, saws, sanders, routers, and planers by a carpenter.

Meaningful and definitive measurements of vibration levels from hand tools have only been obtained in the last 10 years. The state of the art of electronics technology has only recently permitted the development of equipment to analyze these measurements. Fast Fourier Transform Analyzers are needed to perform spectral analysis of vibration levels at various frequencies. Until the advent of semiconductors and later integrated circuits, these instruments were very expensive, fairly large, and few in

number. Size reduction also made field measurements more feasible. Accelerometers capable of measuring vibration from percussive pneumatic tools have only been available in the last few years. The problems with accelerometers stem from the very high impulsive vibration levels that cause destruction of the accelerometers as well as problems of spectral accuracy at the low frequency end of the measurement (referred to as DC shift). The greater number of measurement studies have measured gasoline-powered chain saws (30).

HAND-ARM VIBRATION RESEARCH IN THE UNITED STATES

As early as 1918, studies of Raynaud's Phenomenon in the United States were reported among stone cutters (31, 32) using vibrating hand tools. These workers were studied by Hamilton (3), Rothstein (33), and Leake (34). In 1946 Dart (35) described the effects of vibrating hand tools on 112 workers in the aircraft industry. He noticed that these workers complained of pain and swelling in the fingers and hands; showed an abnormal response to a cold provocation test; and exhibited tenosynovitis. Later in the early 1960s Ashe et al. (8) and Ashe and Williams (9) reported that seven hard-rock miners had been clinically diagnosed as having Raynaud's Phenomenon. Surprisingly, however, Pecora (36) surveyed a group of occupational physicians in the United States about VWF and concluded: "A preliminary survey of the literature on the incidence of Raynaud's phenomenon of occupational origin in this country revealed a conspicuous lack of information concerning both the number of workers affected and the number using small hand-held vibratory tools. An attempt was made to estimate the number of workers using vibrating tools and the number afflicted with Raynaud's phenomenon of occupational origin. All of the information thus gathered indicates that Raynaud's phenomenon of occupational origin may not be completely evaluated, but it may have become an uncommon occupational disease approaching extinction in this country."

The next occupational hand-arm vibration studies in the United States did not occur until 1974 when a survey carried out by the National Institute for Occupational Safety and Health (NIOSH) indicated that an estimated 8 million workers were exposed to occupational vibration in U.S. industries (37). Some 6.8 million were exposed to whole-body vibration and some 1.2 million to hand-arm vibration. These estimates were based on surveys of a multiplicity of U.S. industries. In 1974, Williams (who had collaborated with Ashe in the early 1960s) and Byrne completed another study for NIOSH (38). This study was an attempt to determine the quality, quantity, and availability of suitable health records (from which NIOSH might later conduct epidemiological studies that would identify and quantify the occupational hand-arm vibration problem). Although this study was not exhaustive, the results indicated that of the few records available in the United States, the records of companies employing large numbers of workers using vibrating hand tools were the best. Particularly disturbing, however, were William's reports of informal talks with some workers whose hands appeared blanched. Many of these workers told him that they knew they had Raynaud's Phenomenon, but lived with it and tolerated it because they feared loss of employment should they report the malady (38). In October 1975, NIOSH held an international, occupational, hand-arm vibration, conference to discuss in depth the epidemiologic, medical, physiological, and engineering aspects of VWF and vibration measurements. The presentations and discussions were later published as a Proceedings (39). The conference summary and recommendations follow:

1975 NIOSH Hand-Arm Vibration Conference Summary and Recommendations

1. Epidemiological and followup medical field studies of chain saw operators in England, Sweden, and Poland indicate that in unexposed populations the prevalence of "white fingers" is 6 to 8% and, in the vibration exposed groups, the prevalence varies from 6 to 89%. As a result of these studies (and competitive pressures), numerous chain saw manufacturers have changed their tool designs to incorporate antivibration mounts. To reduce the number and severity of VWF attacks, additional corrective measurements, such as wearing gloves, heated rest shelters, and warm clothing, have been introduced by the U.K. Forestry Commission to maintain constant core body temperature.

2. The interval of time between the first exposure to vibration and the first appearance of a white fingertip has been designated "the latent period." This period varies from 1 to 5 years, with a mean of between 2 to 3 years in chain sawyers. In the limited field studies that have been performed on pneumatic tool and pedestal grinder operators, the latent interval can vary from less than 1 year to as long as 8 to 10 years, depending on the vibration exposure, the time, and the intensity of the vibration. As a result of these studies, a white finger classification system has been devised to define stages of severity.

3. Examination of chain saw operators has led to an emphasis on the actual measurement of the vibration impinging upon the workers and attempts to correlate these measurements with medical data. Evidence from longitudinal prospective studies performed in England and Sweden, suggest that the new antivibration chain saws have reduced the prevalence of white fingers.

4. There was general agreement of the need to develop objective tests to diagnose VWF and identify the severity of the disease. Although the variety of neurological, temperature, and vascular tests (previously studied) differentiated statistically between vibration-exposed and control groups, they failed on an individual basis.

5. In order to redesign their tools intelligently, chain saw manufacturers and manufacturers of other vibratory hand tools require a dose-response relationship from the medical data and vibration measurements. Until such time, designers cannot assume that antivibration tool design will reduce the prevalence of white fingers. To date, statutory regulations for vibrating tools have been imposed in only a few western countries.

6. Unlike the chain saw field, little or no data are available on pneumatic tool work processes. To date (1975), there are virtually no morbidity data or reliable vibration measurements of workers operating pneumatic tools or electrical grinding tools. A definite need exists for studies that will accurately define the dose-response relationship of workers using pneumatic tools.

7. This conference emphasized the difficulties in performing engineering measurements on percussive tools that have attendant high acceleration levels. These levels sometimes result in destruction of the measuring accelerometers.

8. Engineering models of the hand-arm system and their relation to vibratory tools have been devised; however, their validity must be tested.

9. In the early 1960s, it was claimed that occupational white fingers in the United States was nonexistent. This claim was probably incorrect since recent estimates indicate that approximately 1.2 million workers are exposed to hand-arm vibration in the United States.

10. The FAO/ECE/ILO Joint Committee on Forest Working Techniques appealed at this conference for worldwide medical monitoring of vibration-induced white fingers and a uniform reporting system identifying faulty chain saws.

This conference became a major catalyst for subsequent NIOSH hand-arm vibration activities, with recommendations 4 through 9 (inclusive) acting as the basis for this study.

PRESENT STUDY DEVELOPMENT

After the Conference ended, the NIOSH Vibration Study Team obtained the interest and cooperation of both labor and management to conduct a study of pneumatic chipper and grinder workers at multiple plant sites. A preliminary study protocol was drafted, and in January 1977 a meeting was held to finalize the study protocol. At this meeting of representatives from labor and management, occupational physicians, and knowledgeable international consultants, it was agreed that:

1. Laboratory studies were needed to confirm the field study usefulness of the proposed objective clinical tests (recommendation 4 above).

2. Additional engineering work would be needed to assure that measuring transducers would not be destroyed during vibration measurements (recommendation 7 above).

Consequently, from January 1977 through September 1977, the following activities occurred:

1. A series of laboratory studies were performed to confirm two proposed objective clinical tests photocell plethysmography (40) and aesthesiometry (41).
2. Associated, new, and patentable instruments (41, 42) were developed for both laboratory and field use.

3. Additional engineering work (recommendation 8 above) and better methodology were developed to obtain accurate vibration measurements from pneumatic chipping tools.

4. For the field study, a 45-foot trailer was obtained and outfitted in-house to carry on the medical-clinical and objective diagnostic testing.

5. A customized engineering truck (43) was modified in-house to meet the study needs for engineering testing.

In October 1977, a "dry run" of the entire field study procedure was done using 16 NIOSH volunteer employees. The total testing time per subject averaged 2 hours and 15 minutes.

In January 1978, the Vibration Study Team began onsite field testing of chipper and grinder workers, which represents the content of this report. Data were collected for 8 weeks and 385 volunteer workers were tested. The field examinations were made at two large, gray-iron foundries and one shipyard. Data collection ended with the additional examination of 50 stone cutters in Bedford, Indiana--the exact location where 60 years earlier Dr. Alice Hamilton first described VWF in the United States (the results of the Bedford study are presented in a separate paper (44)).

RAYNAUD'S PHENOMENON OF OCCUPATIONAL ORIGIN

MEDICAL-CLINICAL CRITERIA

It is essential that Primary Raynaud's Disease as originally described by Raynaud (and sometimes known as "Constitutional Cold Fingers") be distinguished from Raynaud's Phenomenon of Occupational Origin (also called Vibration White Fingers or VWF).

The physiological cause of Raynaud's Phenomenon of Occupational Origin and of Primary Raynaud's Disease is not known (45). Vibration may directly injure the peripheral nerves, thereby causing numbing of the fingers and hands or the paresthesia of the hands may be secondary to the vascular constriction of the blood vessels causing ischemia of the peripheral nerves. Likewise the physiological or chemical changes occurring in the blood vessels or blood due to vibration can only be speculated upon at this time (46). Whatever the etiology, it is necessary to distinguish all individuals with medical conditions giving rise to impaired circulation of the fingers or sensory changes in the hands. Individuals having these medical conditions are classified as either cases of Primary Raynaud's Disease or as cases of Secondary Raynaud's Phenomenon due to causes other than vibration.

For individuals with a history of vibration exposure, the time of disease onset differentiates cases of Primary Raynaud's Disease from those with Raynaud's Phenomenon due to vibration. Primary Raynaud's Disease can be established by the onset of blanched digits and greater sensitivity to cold stimulus (than in normal subjects) prior to exposure to vibration and entrance into industry. There may also be a strong family history of white, cold hands.

Secondary Raynaud's Phenomenon due to causes other than vibration may be attributed to numerous medical conditions (see Table 1). Individuals with collagen diseases (connective tissue diseases) who have a history of white finger attacks due to cold and such diseases as systemic lupus erythematosus, scleroderma, and rheumatoid arthritis must be separated from cases of VWF. Cases with interference of the blood vessels leaving the thoracic cage, such as costo-clavicular and hyper-abduction syndromes, confound a diagnosis of VWF as do neurogenic disorders such as poliomylitis and syringomyelia. Cases with vascular disorders such as Buerger's disease, generalized atherosclerosis, and a long history of raised blood pressure present symptoms similar to VWF and must be considered separately. Other cases are distinguished who have abnormal configuration and distribution of the radial and ulnar arteries in the forearm and palms, as revealed by clinical examination of the pulses. Trauma of the hands and fingers from

certain fractures, lacerations and operations can disturb the peripheral circulation as does frostbite of the fingers and hands.

Taylor and Pelmear (18) have given a clinical description of VWF: "The early clinical manifestations of VWF are, as early reports emphasized, trivial. At first the signs and symptoms of VWF pass unnoticed, do not interfere with the work situation and there is no interference with either social activities or recreation. Slight tingling and/or numbness of the fingers is noticed, followed later, and this may take years, by an attack of finger blanching confined in the first instance to a finger tip and, subsequently, with further vibration exposure, extending to the base. The provocative agent is cold but there are other factors involved in the trigger mechanism, e.g., central body temperature, metabolic rate, vascular tone of the vessels (early morning, especially, prone to attacks) and emotional state. An attack will last 15-60 minutes but in advanced cases may extend from 1 to 2 hours. The recovery phase is signalled by the appearance of a red flush -- a reactive hyperaemia -- usually seen in the palm and advances from the finger base. Due to repeated ischaemic attacks in advanced cases, touch and temperature sensation is impaired. There is a loss of dexterity and an inability to do fine work. Eventually, with further vibration exposure the number of blanching attacks is reduced to be replaced by a dusky, cyanotic appearance of the digits leading to nutritional changes in the finger pulps. Ultimately, small areas of skin necrosis appear at the fingertips."

To estimate the severity of the white finger condition, this study used a system that Taylor successfully developed and used (18, 39, 47, 48). From the results of a clinical interview (occupational and health history, and the degree of social impairment and interference with hobbies) and a clinical examination, the white finger sufferer is placed into one of the stages in Table 2.

At stages 1 and 2, attacks as described above occur mainly in the winter and especially during the early morning, either at home or enroute to work (as a result of cold steering handles or wheels of vehicles). Employees outside in all weather are most prone to early morning attacks, e.g., forestry workers with long vibration exposure. Previous studies have shown that as vibration exposure time increases, the number of VWF attacks tends to increase (18,48). During stage 2, employees may report interference with or limitation of activities outside their work, e.g., gardening, fishing, swimming, car washing, home car maintenance, and woodworking. These activities have one factor in common: they may be done in a reduced environmental temperature which triggers an attack of VWF.

In stage 3, there is definite cessation of hobbies, thus curtailing the subject's enjoyment of his leisure. VWF attacks will occur in summer as well as winter. Other problems that arise are interference with work, particularly out-of-door work (such as forestry); difficulty in undertaking fine work such as electronics; difficulty in picking up small objects such as coins; difficulty in buttoning and zippering items of clothing; inability to distinguish between hot and cold objects; and clumsiness of fingers with increasing stiffness of the finger joints.

In stage 4, the severity of the VWF and the interference with work, social activities, and hobbies are such that the subject must change his occupation. In the severest forms, the arteries of the fingers are obliterated by the closure of the lumen. This sequence of progressing stages arises from the cumulative effect of vibration transmitted to the hands with the regular, prolonged use of vibrating tools found in certain industrial processes. Despite a considerable amount of research, little is known about the basic physiology of VWF. Also little is known, with any degree of precision, about the vibration parameters (vibration acceleration, spectrum, and energy into the hand) responsible for the resulting VWF.

OTHER COMPLICATIONS OF RAYNAUD'S PHENOMENON OF OCCUPATIONAL ORIGIN

A multitude of medical conditions have been thought to be associated with VWF. Some of these relationships have been examined experimentally or in field studies, others have not. Some of these relationships are discussed here:

Callus

Edsall (49) observed that callus formation on the palmar surfaces of the fingers was particularly noticeable on stone cutters using pneumatic hammers. "Hard pads of thickened skin are usually seen on the fingers exerting the most pressure on the vibrating tool or metal object, but a general swelling of one or more fingers is also quite common." Stewart and Goda (50), in noting the callus on the finger pads of vibration-exposed persons, hypothesized that this was the cause of vibration white finger. They suggested that the callus formation results in a fall in the volume of blood that can be held in the capillaries in a segment of the finger, and in the ability of the capillaries to react to changes caused by either a rise or fall in body temperature. Thus, temperature-induced changes in the blood volume may become visible--the hands become "cold-weather sensitive". No pathological or physiological evidence is given to support Stewart and Goda's hypothesis.

Nerve Injury

The early investigators in the United States mentioned some decrease in sensory perception in the affected hand. Subsequently, Hardgrove and Barker (51) described permanent sensory changes in the hands that did not follow peripheral nerve trunk distribution, and Junghanns (52) noted a disturbance in the sense of touch and in sensitivity to cold in the fingers.

Seyring (53) drew attention to three people with wasting of the muscles of the hand and loss of sensation in the areas supplied by the ulnar nerve. She attributed this to pressure on the nerve. Hunter et al. (25) also observed ulnar paralysis.

Brockelhurst (54) found that touch sensation was normal but that thermal sensation in the fingers, especially the tips, was impaired. Decreased sensory perception in localized areas is frequently thought to be caused by localized trauma. Dart (35) observed that localized loss of sensation may

result from injuries to more proximal portions of the nerves. Pyykko (55) found that 81% of his population of lumberjacks who used chain saws experienced numbing of the hands especially at night. He attributed this to nerve damage. Peters (56) reported pain, throbbing, and burning in those fingers most intimately in contact with the vibrating tool. He also reported that workers' hands felt numb and frozen. He found a positive correlation between the method by which the tool was held and the sensory changes. Sensation to touch, pain, and temperature in that portion of the hand in closest contact with the tool was diminished or absent. Marshall et al. (57) also noted impaired sensibility to light touch and pinprick. From observations on pneumatic tool operators, Mikulinskii (20) confirmed that exposure to vibration causes an increase in the threshold of sensitivity in the hand most exposed.

Bone Cysts

From work done on chain sawyers and controls, James et al. (58) found vacuolar formations (or cysts) in the bones of the wrist and hand, and concluded that the differences between the occurrence of cysts in controls (33%) and vibrated workers (44%) were not statistically significant.

Other X-ray testing has identified decalcification and vacuoles in the carpal bones (25, 59), osteolysis of the distal phalanges (59, 60), and deformations of the metacarpal and carpal bones (61) in vibration exposed workers. In all instances, the lesions had been related to severe or recurrent trauma. Golding (61) has also remarked that small cysts can occur with recurrent mild trauma or as a result of severe trauma. Esau (62) reported that single cysts can occur in the carpus and can involve more than one bone. Brailsford (63) has reported cysts in pneumatic drill users.

Muscle, Bone, and Joint Disorders

Farkkila et al. (64, 65) have reported a decrease in muscle force in chain saw operators, with the maximal decrease occurring during vibration exposure.

Agate et al. (21, 66) reported skeletal changes in regions of the wrist and elbow joints. Low frequency vibration (less than 100 Hz) is transmitted through the hands as far as elbow and shoulder joints with possible arthritic and periarticular changes occurring. Bovenzi et al. (22) found radiological signs of osteoarthritis at the wrists and shoulders in a population of shipyard caulkers using pneumatic chipping hammers and grinders.

In addition, the following disorders have been related to vibration exposure: joint pain and stiffness, tendonitis of fingers and wrists, and carpal tunnel syndrome and Dupuytren's contracture involving the palmar fascia. Because numerous systems other than hand blood circulation have been related to vibration exposure, the terminology of "Vibration Syndrome" is often used to describe the combined effects of the exposure (67).

STUDY OBJECTIVES AND PROTOCOL

The following study objectives and protocol were established at the January 1977 meeting (see Present Study Development).

STUDY OBJECTIVES

1. Determine if VWF exists in certain U.S. worker populations by comparing the prevalence of VWF in control groups and vibration-exposed groups of workers operating selected pneumatic hand tools in certain work situations.

2. If VWF does exist, relate its occurrence to vibration exposure time and vibration characteristics of hand-held tools.

3. Establish preliminary vibration guidelines for preventing VWF in the occupational groups studied.

4. Investigate the validity of certain physiological and clinically objective tests for early detection of VWF.

5. Based on the results of 2 and 3 above, provide preliminary technical guidelines to tool manufacturers for reducing vibration in the tool types studied.

PROTOCOL

A comprehensive survey of workers would be performed. Those using pneumatic hand-held chipping and grinding tools would be studied. Voluntary participation in the study was asked of companies with large numbers of pneumatic chipping and grinding workers. These companies had been identified during previous NIOSH surveys (37,38). All shifts would be examined. All study participants would be volunteers who would be subjected once to:

1. An interviewer-administered questionaire consisting of a non-medical (especially occupational history) and medical portion.

2. A general medical examination to detect medical problems that may confound a diagnosis of VWF.

3. The following clinical tests: skin temperature, light-touch sensing, pain (via pin prick) sensing, and temperature sensing.

4. A special medical history and finger examination to diagnose the presence of white finger or VWF.

5. Noninvasive (i.e., does not pierce the skin) objective medical testing which would include:

   a. X-rays of both hands (Anterior-Posterior and lateral)

   b. depth sense and two-point discrimination

   c. photocell plethysmography

6. Engineering tests for a sample of workers would measure vibration energy impinging upon both hands of participants. The technique used (called dynamic compliance) involves grasping a handle (in a variety of hand orientations) attached to a small electronically driven table-top shaker. Various vibration frequencies are sequentially applied to the shaker in a swept fashion from 5 to 1000 Hz. A vibration impedance transducer is sandwiched between the handle being grasped by the subject and the moving piston of the shaker; from this transducer, energy impinging upon the hand can be determined by calculation. The subject's grip strength would also be measured. Exposed and control groups would be compared.

Total testing time per subject for the above procedures would be 2.5 hours. As required under U.S. Law, strict confidentiality of individual worker identity as well as individual medical information would be (and has been) maintained throughout this study. In addition to the above individual worker tests, the following engineering measurements would be made.

Once the types and models of the chipping and grinding tools had been ascertained, a few of the exposed workers would be asked to work with these tools at a work station. Measures of vibration would be obtained while a chipper/grinder worker used the tool. Vibration amplitude (i.e., acceleration) and vibration signature (i.e., spectrum) would be analyzed. In addition, the time per day a tool is used and the various hand-arm positions during use would be investigated. Engineering measures would be related to a standardized biodynamic coordinate system established by the International Standards Organization (ISO).

The results of engineering testing are discussed in Volume II (68) of the study report. The results of the objective clinical tests will be published in scientific journals at a later date.

Subsequent sections of this report will review in detail the questionnaire results and medical-clinical data analyses and results.

METHODS: MEDICAL-CLINICAL TESTING

OVERALL TESTING SEQUENCE

The medical-clinical testing was carried out in a specially designed 45-by 10-foot climate-controlled trailer (see Floor Plan, Figure 1). When possible, exposed and control subjects were tested at random. Subjects entered and reported directly to the reception station (I) where they were logged in and given gloves to warm their hands. The subject then proceeded to station II where voluntary consent forms and details concerning confidentiality were explained and signed; the study questionnaire was then administered. Next, the subject moved to station III where a general medical examination was performed. At station IV, the subject's hands were tested for temperature, and tests were conducted for light touch, pain, and temperature sensing. Then additional medical history was taken. At station V, X-rays of each hand (both AP and lateral) were taken and immediately processed. The subject then moved to station VI where depth-sense and two-point discrimination tests were done. At station VII, photocell plethysmography was performed. (This represented the last testing station for all but a sampling of workers who proceeded to station VIII where the dynamic compliance testing was done.) Each subject spent approximately 2 hours in the medical trailer (and some spent a half hour in the engineering truck for dynamic compliance testing).

Log-In (Station I)

As each subject entered the trailer, he was logged in and given a pair of warm workman-type soft gloves. He was instructed to wear the gloves at all times except during the test periods, to keep his hands warm. Taylor and Pelmear (18, 47, 48) have found that hand testing cannot be done with cold hands and/or during a VWF attack, (which is usually precipitated by cold).

Study Questionnaire (Station II)

The subject consent form (see Appendix A) was used to brief each volunteer and obtain their consent to participate voluntarily in the study. The subject signed one copy and retained an identical version of what was signed.

The questionnaire (see Appendix B) which was then administered by experienced and trained interviewers, contained the three parts:

Part I - Demographic data such as ethnic group and date of birth; present (i.e., at the time of the survey) and past occupational history and hobby tool history (see Table 3).

Part II - An individual medical history concerned with white finger and medical problems that confound a diagnosis of VWF; blood-relative medical history; and medication usage.

Part III - Smoking and alcoholic consumption histories.

Medical Examinations (Stations III and IV)

Each subject was examined sequentially by two physicians. The data recorded by the first physician was used to screen subjects for Raynaud's Phenomenon or White Finger due to causes other than vibration. The second physician performed clinical sensory tests and diagnosed the presence or absence of White Finger or VWF. The medical examination by the first physician included the following:

1. Systolic and diastolic blood presssures taken twice on right and left arms.

2. The radial, brachial, dorsalis pedis, and tibialis anterior pulses, both right and left.

3. The rate and rhythm of the heart and presence of murmurs.

4. Arm inspection for trauma, scars, deformities, skin lesions, and needle marks.

5. Hand examination for trauma, blanching, cyanosis, hyperaemia, skin lesions, scars, lacerations, and calluses.

6. Finger examinations for amputations, blanching, cyanosis, calluses, finger tip ulcers, joint swellings, knuckle pads, scars, lacerations, trauma, fractures, and finger swelling.

7. Wrist and finger mobility.

8. Detection of tendonitis, carpal tunnel syndrome, Dupuytren's contracture, and arthritis.

As a precautionary measure, subjects with raised blood pressure (as determined by the first physician), or who had a history of cardiovascular disease were allowed to continue testing up to, but not including, Station VII (photocell plethysmography).

The following tests were performed by the second physician:

1. Skin temperature (finger tips, webs, and palms) was measured with the use of a Yellow Springs thermistor mounted on a small, pencil-like wooden dowel; the reading was taken on a Yellow Springs Readout. If the temperature was below 30°C, the hands and fingers were warmed by gloves until the skin reached that temperature.

2. Light-touch (anterior and posterior aspects of wrists, palms, and digits) using a swath of cotton brushed across these areas.

3. Pain induced by pinprick (anterior and posterior aspects of wrists, palms, digits).

4. Temperature sensing (anterior and posterior aspects of wrists, palms, digits) locally applied at a constant 40°C. A new, pencil-type soldering iron with a round, flat tip was plugged into the output of an AC variable line transformer (Superior Electric Co.). The line voltage (and, hence, the iron tip temperature) was adjusted to produce a constant 40°C tip temperature, which was periodically monitored during the test day.

After performing the clinical sensory tests, the second physician took a medical history and did a special examination of the fingers and hands. The second physician assessed a preliminary stage for the subject at the end of his examination and tests (according to the stages of VWF given in Table 2).

The subject then moved to Station V (X-ray), Station VI (depth sense and two-point discrimination), and Station VII (photocell plethysmography). A sample of subjects also went to Station VIII (dynamic compliance). The study team members at Stations V, VI, VII, and VIII did not know or have access to the preliminary stage assessment. They also did not know the results of the interview or examination.

At the end of each day of testing, both physicians reviewed the medical data without knowing or considering the results of the objective clinical testing (i.e., X-ray, depth sense, two-point discrimination, and photocell plethysmography), and they decided upon a final stage assessment.

WORKSITES AND WORKPRACTICES

Three workplace sites were investigated in this study: two gray-iron foundries and a shipyard. The pneumatic tools used in the foundries and shipyard were Type 2 chipping hammers, vertical grinders, and horizontal grinders. These same tool types are competitively made by various manufacturers.

The chipping tool (also called an impact hammer) generally produces 2100 blows/minute (corresponding to a 35-Hz repetition rate). It weighs about 12 pounds and its length can vary from 12 to 15 inches (depending on the manufacturer). The diameter of the rear handle is approximately 1.5 inches. The diameter of the chisels used with these hammers is approximately 3/4 inch, while the chisel length can vary from a few inches to 2 feet. The characteristics of the working end of the chisels differ somewhat depending on the chisel application. The worker must be able to change chisels quickly; thus the chisel is inserted freely into the bore of the chipping hammer barrel and is not usually retained by the hammer barrel while in use. The chisel, if not held by the operator's hand or not working against resistance, will shoot out of the barrel; therefore, most operators grasp the chisel at all times while using the chipping hammer. The foundries studied used pneumatic horizontal grinders accommodating 6- or 8-inch grinding wheels. These units rotate from 4500 to 6000 rpm (corresponding to 75 to 100 Hz). They weigh about 14 pounds and their length is from 20 to 25 inches. Vertical grinders were used in the shipyard that accommodated similar grinding wheels and ran at about the same speed as the horizontal grinders. The vertical grinders weighed about 8 pounds.

For all these pneumatic tools, air pressure was in the 90 to 110 psi range. Each of the three worksites studied had a central tool crib and a repair/ maintenance station for these tools.

A description of the work situation for each of the foundries and shipyard follows.

FOUNDRY NO. 1

Foundry No. 1 was a large, high-volume production, gray-iron foundry manufacturing large castings weighing more than 100 pounds, such as vehicular castings (engine blocks, transmission cases, etc.). The casting metal used was a gray iron that falls under the Class 30 Gray Iron designation. This type of metal is a pearlitic (nodular) iron having a minimum of 30,000 psi tensile strength with a general hardness range of 187 to 255 BHN (Burnell Hardness Number).

Information about workpractices was gained from observations of workers while they used the chipping and grinding tools to clean castings and from discussions with department supervisors and foremen. The men worked in teams of two. Each team's workstation consisted of a semienclosed cubicle (approximately 10 feet long by 5 feet wide). Approximately 20 of these stations were lined up side by side. Compressed air (90 psi) was brought to each workstation to power two Type 2 chipping hammers (with assorted chisels, each from 1 to 3 feet long) and two rotary grinders (with 6- and 8-inch grinding wheels). Each cubicle had a waist-high steel table. Above this table was an electric hoist used to manipulate large castings, which were brought to these workstations via a continuous, overhead, chain conveyor or by a forklift truck containing pallets of castings.

The men on these teams were paid on a piecework basis. After they received the casting at their steel table, one man immediately began chipping the burrs off the visible faces of the casting. The other man followed by grinding the area just chipped. After doing one to three surfaces, they would interchange tools. Sometimes they chipped simultaneously (e.g., one on the surface metal and the other in the deep cylinder cavities of an engine block). All visible surfaces were chipped and ground. A team could completely chip and grind an 800-pound transmission case, for example, in an average of 54 minutes.

On occasion, some castings were "burnt"--sand from the mold had impregnated itself on the casting. These were extremely difficult castings to chip and grind and were usually sent to a single "reclaim/salvage chipper/grinder". This worker was paid as an hourly employee, not on a piecework basis. The ratio of two-man teams to reclaim/salvage chipper/grinders was 10 teams to 1 reclaim man.

The piecework teams operated their chipping and grinding tools at full throttle and used a tightly coupled palm grip to clasp the chipping tool at both ends. Their grip strength was approximately 6 pounds of force for each hand. The hand holding the chisel was always gloved because the chisel became very hot. Occasionally the hand holding the rear handle was gloved. Pneumatic grinders were held in the same way as the chipping tools.

The gloves were of medium weight leather or similar man-made materials. All chippers and grinders wore earmuffs and a ventilated hood connected to a filtered compressed-air supply line (See Figure 2).

Based on observations and discussions with supervisors, in a normal 8-hour shift each chipper and grinder spent an average of 3.5 hours chipping, 2.5 hours grinding, 1.5 hours manipulating and moving castings, and 0.5 hour on break time. The reclaim/salvage (hourly) worker averaged about the same time as the pieceworkers (except that he worked longer on much fewer castings). This plant had about five or six different types of castings.

FOUNDRY NO. 2

Foundry No. 2 is another large, high-volume production, gray-iron foundry manufacturing small (less than 100 pounds) vehicular castings (oil pans,

manifolds, etc.). The casting metal was the same type as that used in Foundry No. 1.

In this plant, the chippers and grinders were not teamed and each man was paid on a piecework basis. Castings were brought to the workstation via a forklift truck and pallet. A variety of small castings were handled with more grinding than chipping taking place. The same types of tools used in Foundry No. 1 were used here. Chisel lengths varied from 3 to 12 inches and were not, as a rule, as long as those used in Foundry No. 1.

The men in Foundry No. 2 were also incentive workers. Chipping and grinding time varied depending on the casting type, e.g., an 85-pound oil pan took about 10 minutes to complete, whereas a 44-pound manifold took about 1.5 minutes to complete. Here, again, there were a few hourly, reclaim/salvage operators (10 pieceworkers for each reclaim/salvage operator).

Each man wore earmuff hearing protection as well as a ventilated hood. At least one glove was worn and, at times, both hands were gloved, depending on operator preference. The estimated work time was 4 hours grinding, 3 hours chipping, 0.5 hour casting manipulation, and 0.5 hour break time. At the Foundry No. 2 machine shop, setup men were also examined who were not exposed to hand-arm or whole-body vibration.

The training given to workers was discussed with the supervisors. The workers progressed gradually as their skill level increased. A new worker was placed on the midnight-to-8:00 a.m. shift where the workload was lighter than on the other two shifts. As his skill level increased, the trainee was eventually transferred to another shift. Almost no specific training was given regarding a preferred method of working with the vibrating tools.

SHIPYARD

At the large shipyard operation investigated, ship propellers and large ships of all descriptions were built, repaired, and modified. The workers at this shipyard used the same chipping hammer that was used in the foundries, and a rotary type grinder not very different from the foundry type grinder.

Observations of workers using pneumatic chipping and grinding tools and discussions with supervisors in two departments related how the workers used these tools. Department X included men who worked in the holds of ships. Department Y included workers who chipped and ground propellers. All worked on a single daily work shift and all were hourly employees. The metals chipped by workers in both departments were: a nickel-aluminum, bronze alloy, and mild steel.

DEPARTMENT X

The men in this department worked in the holds of ships and used both pneumatic chippers and grinders. They also used other pneumatic tools such as pneumatic drills, saws, riveters, and sanders. An average 8-hour work day consisted of 4 hours of chipping, 2 hours of grinding and other

pneumatic tool use, and 2 hours of performing other nonvibratory activities. On occasion, the chipping could extend to 5.5 hours per day.

One man trained all of the men in this department on the use of pneumatic chipping hammers. All chippers were instructed to use their body for leverage and thereby absorb some of the vibration energy from the chipping hammer. Their arms were to be held close to the body with the arm braced by the body, knee, etc., for extra leverage. Generally, the chipping hammer chisel was guided with the first finger and thumb or the flat palm of the hand. The chisel was rarely in complete contact with the fingers. The back handle was loosely clasped with the fingers. The chippers were trained to hold the chipping hammer in either hand and wore leather gloves on both hands, principally for heat reduction. Generally, they operated the chipping hammers for 15-to 20-minute periods without resting. They also sharpened their own chisels, customizing them to their preferences. The length of the chisel was from 3 to 5 inches.

The men in this department basically performed two types of operations: tamp and cut. The tamping operation included tamping and packing metal and other caulking compounds into holes. Metal was welded into holes and the chippers tamped the metal to form a smooth surface.

To use the chipping hammer for cutting, excess metal had to be removed from the weld. Sometimes, they had to hold the chipping hammer over their heads to perform cutting operations. Workers also used chisels to cut through bulkheads. For these operations the workers guided the chisel with the flat part of the palm while gripping the back handle tightly with the other hand. During nearly all of the chipping, the worker used the chipper at full throttle. The workers used both horizontal and vertical pneumatic grinders to do finishing work.

DEPARTMENT Y

The men in this department cleaned and shaped ship propellers. Because of the high precision required for finishing propellers, the workers progressed very slowly. It was not unusual for a worker to work from 40 to 50 weeks on a newly cast propeller. A worker first chipped the entire surface of one side of a propeller and then ground the surface. When completed on one side, the propeller was turned over and the operations were repeated on the other side.

While chipping a propellor the worker leaned into the chipping hammer with his body, pushing on the back handle of the hammer with the palm of his hand. He guided the 3-to 5-inch long chisel with the palm of his hand. Thus, his fingers never contacted the surface of the chisel and rarely contacted the back handle. Each worker wore one glove on the hand that guided the chisel. The hand that pushed against the back handle remained ungloved so that the worker's hand was free to "feel" the throttle trigger of the hammer. Workers operated this tool at 1/2 to 3/4 throttle. They chipped in 15-to 30-second bursts with a 2-to 3-minute rest period between bursts. On the average, 3 hours per day were spent chipping, 3 hours grinding, and the remainder in nonvibratory activities.

OCCUPATIONAL HISTORIES AND EXPOSURE GROUPS

Interviewer-administered questionnaires were used to obtain data about occupational histories from the 385 male workers participating in the study, (see the Study Questionnaire, Appendix B). The information collected for each job with present and past employers is given in Table 3. A maximum of four jobs with a present employer and five jobs with past employers were recorded in computer files. Present employer refers to the employer at the time the survey was conducted. The occupational histories provided the fundamental information for assigning workers to exposure groups. Data were also obtained about the use of vibrating hand tools during hobby activities (see Table 3). A maximum of three hobbies were recorded.

Verbatim responses of subjects were recorded on questionnaires for the following occupational history and hobby variables: department number, job title, tool types, past employers, type of company, and hobby type. All of these variables except for past employers were numerically coded for the computer files. Frequently more than one tool was listed by workers for each job. Single tools were not given a code, instead unique combinations of tools were assigned different codes. The code descriptions and their frequency of occurrence for these variables are given in Appendix D.
The current job (i.e., the job with the present employer at the time of the survey) was recorded for all workers studied. For jobs other than the current one, only jobs requiring the use of vibrating hand tools were recorded on the questionnaires; this included past jobs with present employers and past jobs with past employers. Table 4 summarizes the number and percent of these jobs.

The occupational history variable "vibrating hand tool used on the job" yielded the most information about exposure to hand-arm vibration. Since the purpose of this study was to investigate workers using pneumatic chipping and grinding tools on their current jobs, tool codes that included a chipping hammer were of primary interest. Grinding tools were included because they are usually used in combination with chipping hammers. Chipping hammers and grinders were not the only hand-held vibrating tools used by the workers studied on their present and past jobs (see Appendix D, Tools). Hand-arm vibration exposure from some of these tools confounds exposure to chipping and grinding tools because their occupational use has been shown to cause VWF.

The information used to determine which tool exposures would confound exposure to chipping and grinding tools was taken mainly from the little vibration measurement data available and the results of previously mentioned, epidemiologic studies. For some of the tools in Appendix D, however, data do not exist. For these tools, as much knowledge as possible

was gathered about their operating characteristics and their types of on-the-job uses. The project's medical and engineering team reviewed all available information on each tool and decided upon a set of tools whose occupational exposure would confound exposure to chipping and grinding tools (see Table 5). Confounding exposure was considered in this study to mean: 1) hand-arm vibration exposure severe enough to produce VWF in a biologically and statistically significant proportion of a worker population and/or 2) vibration characteristics of the tool that are similar to those of the tool studied with the highest vibration levels (i.e. the chipping hammer).

The tools in Table 5 were part of the criteria for exclusion from the group of workers currently exposed to chipping and grinding tools. These currently exposed workers were selected by first examining the current job titles of all workers who reported using a chipping hammer on their current job. Fourteen job titles were identified and all workers with these job titles were examined for tool usage on their current job. For 3 of the 14 job titles, 50% or less of the workers reported use of a chipping hammer on their current job (see Table 6). All of the workers with these three current job titles were from the shipyard group. Workers with the remaining 11 job titles (see Table 7) were considered for inclusion in the exposed group.

The decision diagram in Figure 3 and the selection criteria and tool categories in Table 8 show how workers were selected from the study population for the exposed and control groups. The objective of the selection criteria for the exposed group was to maximize the number of workers in the exposed group without including workers who had confounding exposures, since asssociations between VWF and other factors cannot be demonstrated to be statistically significant without a sufficiently large exposed group.

The objective in selecting the control group was to choose workers who had not used vibrating hand tools but had similar occupational backgrounds and working environments to the exposed group. The control workers selected in this study have never used vibrating hand tools on any of their jobs. This criterion is strict but was considered necessary to increase the likelihood of finding differences between exposed and control workers. A discussion of each exposure group follows:

THE EXPOSED GROUP - EXPOSURE GROUP 1

Two hundred and fifty-nine workers with current jobs having job titles listed in Table 7 (i.e. current job title for chipper) were considered for inclusion in the exposed group. Twenty-four of these workers were excluded from the exposed group because of confounding exposures on present and past jobs and activities off the job.

Three chippers reported using riveting hammers and one reported using a jackhammer on current jobs in combination with a chipping hammer. All four workers were from the shipyard. The riveting hammer, formerly a common tool in the shipyard industries, is now used infrequently, but the jackhammer was

deemed to confound chipping hammer exposure. Gasoline-powered chain saws would also be considered incompatible but no workers reported using this tool in combination with a chipping hammer. Thus, one worker was excluded from the exposed group for jackhammer use on his current job. On past jobs, workers with current job titles of chipper, reported using jackhammers, riveting hammers, and air tampers in combination with chipping hammers. Again only the jackhammer/chipping hammer combination was rejected if the past job was for more than 4 months duration, or if for less than 4 months duration and the current job was of less than 12 months duration. This time restriction was applied to the use of any of the tools in Table 5 when not used in combination with a chipping hammer. This selection criteria for past jobs excluded 18 more workers from the exposed group and placed them in exposure group 6 (see below for details of exposure group 6).

Workers who used the tools in categories C and D (see Table 8) on past jobs for less than 4 months (total of all past jobs with C and D tools) when they had held their current job for greater than 12 months were included in the exposed group. This criteria was applied because it seemed unnecessarily strict to exclude workers who had used these tools, especially jackhammers and chain saws, on single summer jobs or for very short-term employment (mostly as general laborers).

Five workers were excluded from the exposed group because of exposure to vibrating hand tools in Category E that had occurred during off the job activities or hobbies. Four of these five workers had used gasoline-powered chain saws for more than two years off the job (see below under exposure group 7).

In summary, 235 workers were included in the exposed group. Of these workers, four (see Table 7) did not report using a chipping hammer on their current job, but all these workers reported using pneumatic grinders. They were nevertheless included in the exposed group. Appendix E shows the distribution of tool usage for current and past jobs among the exposed group.

THE CONTROL GROUP - EXPOSURE GROUP 2

Workers were selected for the control group who had never used a vibrating hand tool on any jobs, present or past. In addition, workers who used hobby tools in Category E were not included in the control group. Only two potential control workers had significant hobby exposure and were placed in exposure group 8. Seventy-two workers met the criteria for a control; 51 of them from the foundries and 21 from the shipyard. Seven of the acceptable control workers had used a hobby tool from Category F.

EX-CHIPPERS - EXPOSURE GROUP 3

Workers who did not use a chipping hammer on their current job and did not have a current job title for a chipper but had held at least one past job where they had used a chipping hammer were called ex-chippers. The effects of not being currently exposed to hand-arm vibration upon the reversibility of VWF are not known. For some severe cases of VWF, the disease is irreversible. It is not known how the reversibility of VWF varies with

individual health histories, length of exposure, type of exposure, length of time since last exposure, etc. These factors complicate the analysis of risk of VWF in the ex-chippers group. It was not within the design of this study to attempt to answer questions about ex-chippers and VWF. The number of ex-chippers tested was relatively small (30 workers) and ideally would have been nonexistent, but the circumstances of field studies require that some workers be tested who may not be included in the data analysis.

MIXED PAST EXPOSED - EXPOSURE GROUP 4

Workers who did not use any vibrating hand tool on their current job but used a tool in category B or C on at least one past job were placed in exposure group 4. Most of these workers were brought to the testing station as potential control subjects, but their occupational histories revealed past hand-arm vibration exposure.

MIXED CURRENT EXPOSED - EXPOSURE GROUP 5

Workers who did not have a job title as a current chipper, but used any type of vibrating hand tool on their current job and had not used a chipping hammer on any past jobs were placed in exposure group 5. Some of the workers in exposure group 5 were potential exposed subjects who did not have a job title as a current chipper (some of the workers in Table 6) or were potential control subjects such as mechanics and electricians who currently used vibrating hand tools.

CHIPPERS WITH CONFOUNDING EXPOSURES - EXPOSURE GROUP 6

The selection criteria for exposure group 6 was explained above under the exposed group. Nineteen current chippers had conflicting exposures that caused them to be excluded from the exposed group. On past jobs that had not included a chipping hammer, 1 worker had used a gasoline-powered chain saw, 1 worker a riveting hammer, 1 worker an air tamper and 15 workers a jackhammer. One worker had used a jack hammer on both his current and a past job.

EXPOSED WITH SIGNIFICANT HOBBY EXPOSURE - EXPOSURE GROUP 7

Five workers were excluded from the exposed group for significant hobby tool use. Four workers had used gasoline-powered chain saws for at least 2 years and as long as 12 years; one worker reported using "pneumatic tools", including pneumatic grinders in auto bodywork.

CONTROL WITH SIGNIFICANT HOBBY EXPOSURE - EXPOSURE GROUP 8

Two workers who had used gasoline-powered chain saws as hobby tools for two years were excluded from the control group.

Table 9 summarizes the number of workers in each exposure group totally and by industry.

DIFFERENTIAL DIAGNOSIS

In this study every worker was examined by two physicians. The first physician performed a generalized medical examination and the second physician a special examination of the hands and fingers. The data collected during these examinations (see Methods: Medical-Clinical Testing) were used along with health history and medication usage data from the study questionnaire to determine if workers had secondary Raynaud Phenomenon attributable to causes other than vibration. (The section "Raynaud's Phenomenon of Occupational Origin" discusses the medical conditions that may produce a manisfestation of Raynaud's Phenomenon.)

The initial diagnosis and staging for Raynaud's disease and phenomenon were made before any determinations of the medical conditions that confound a diagnosis of VWF. The final differential diagnosis for VWF was made after the data were collected (except for cases of Primary Raynaud's disease, which were diagnosed at the time of the survey). For all cases of secondary Raynaud's phenomenon, the determination was carried out by the physicians without knowledge of the workers' employment and exposure histories and the white finger staging. For exposed workers with a positive diagnosis of secondary Raynaud's Phenomenon, the separation of workers into those with "white fingers (WF)" and those with "vibration white fingers (VWF)" is based upon the presence (WF cases) or absence (VWF cases) of any confounding medical conditions that could explain the signs and symptoms of Raynaud's Phenomenon.

Table 10 lists the medical conditions found among workers in this study that could cause them to be classified as cases of secondary Raynaud's phenomenon due to causes other than vibration. In this report, these workers are called "medical exclusions". Some workers with these medical conditions (especially frostbite and lacerations of the digits) were not considered medical exclusions. Workers were ultimately considered medical exclusions according to the clinical judgement of the examining physicians. Some of these medical conditions were found in as few as one worker; therefore, for purposes of confidentiality, these medical conditions were grouped into five medical exclusion groups (see Table 11). Table 12 gives the frequency and proportion of workers in these five groups for the total population and by industry. For secondary Raynaud's Phenomenon due to causes other than vibration, workers were assigned to only one medical exclusion group; if they had Primary Raynaud's disease and another condition, they were assigned to the Primary Raynaud's group. The prevalence of Primary Raynaud's Disease in this population is very small (2.6%).

The relationship between medical exclusion groups and exposure groups is shown in Table 13. Medical exclusion groups 1 through 4 (from Table 11) and exposure groups 3 through 8 have been combined in this table. Some observations about Table 13 are necessary. The proportionate contribution by the

exposed group to the study population is relatively unchanged before (fourth column) and after (first column) the workers in the medical exclusion groups have been subtracted out. Although the prevalence of Primary Raynaud's disease is lower in the exposed group (1%) than in the control group (4%), the sum proportion of medical exclusions in the exposed group (13%) and control group (12%) is essentially the same. Both these observations indicate that the distribution of medical exclusion cases in the exposure groups is similar, and eliminating them from some analyses will not bias the results.

The WF staging for medical exclusion cases is given in Tables 14. As this table shows, not all medical exclusion cases have WF disease because the physicians designated workers as medical exclusion cases without knowledge of their White Finger staging. The proportion of medical exclusion cases who have advanced stages of WF (i.e. stages 01, 02, and 03) is almost the same in the exposed group (4.7%) and the control group (4.2%). This observation adds to the basis for leaving medical exclusion cases out of further comparative analyses. The number of medical exclusion cases is small, and they do not contribute substantial information; however, leaving them in the analyses may produce bias. RESULTS GIVEN IN THE REMAINDER OF THIS VOLUME ARE FOR WORKERS WHO ARE NOT IN ANY OF THE MEDICAL EXCLUSION GROUPS.

VWF STAGING AND LATENCY

As stated previously, the results given in the remainder of this volume are for workers who are not in any of the medical exclusion groups. Table 15 presents the VWF staging for workers in the study by exposure group and industry. As expected, all of the workers in the control group did not have VWF (i.e. stage 00) after medical exclusion cases were eliminated. The results in Table 15 have been summarized in Table 16. This table shows the prevalence of VWF in the exposed group. The prevalence of VWF (stages 01, 02, and 03) in the two foundries was higher than in the shipyard population. The overall population VWF prevalence is strongly influenced by the VWF prevalence in the foundries which had a larger study population than the shipyard. Chi-square tests for association between exposure and VWF were carried out for the exposed and control groups, with and without medical exclusion cases, for the total population, and by industry. All tests were highly significant (p less than 0.0001), which confirmed a statistical association between hand-arm vibration exposure and VWF.

Three primary symptoms are important in diagnosing VWF: 1) blanching, 2) numbness, and 3) tingling of the fingers. The VWF staging reflects the importance of these symptoms, which people with VWF often will have after exposure to cold or during sleep. Workers in this study were asked about these symptoms during questionnaire interviews before they were clinically interviewed, examined, and diagnosed by the physicians, and again when clinically interviewed. Table 17 is a comparison of the questionnaire responses for these VWF symptoms and the VWF staging from the clinical diagnoses. This table displays the consistency of reporting for these different methods of collecting the same data variables. An inconsistency existed between the questionnaire and diagnosis data in only seven workers. The data for these seven workers were reviewed by the project medical doctors; Table 18 gives the explanations for these inconsistencies.

When a worker reported symptoms of finger blanching, numbness, or tingling, the location of these symptoms on the fingers were recorded for each finger segment (see Study Questionnaire, Appendix B). Tables 19 through 22 summarize symptom location data for workers in the exposed group. Some observations about the data presented in these tables follow:

1. For all three symptoms the thumb was less affected than the other fingers. The thumb on the throttle of the chipping hammer was more affected by all three symptoms than the chisel thumb. Workers reported more numbness and tingling of the thumb than blanching.

2. For all symptoms and fingers the distal segment of the fingers was most affected and the proximal segment least affected (with the middle segment in between).

3. The middle finger on each hand was most affected by all three symptoms.

4. Exposed workers reported blanching on both hands, but they reported more blanching on the chisel hand (i.e., the hand on the chisel of the chipping hammer).

5. For workers reporting blanching of the fingers, the fingers on each hand were affected in the same order: the middle finger most affected, then ring finger, index finger, little finger, and the thumb least affected.

6. For exposed workers reporting numbness and tingling, the hand on the throttle was more affected by these symptoms than the chisel hand.

7. For reports of numbness, the middle, ring, and index fingers on each hand were similarly affected, while the little finger and thumb were less affected.

8. For reports of tingling the middle finger was most affected; the ring and index fingers were similarly affected, and the little finger and thumb less affected on each hand.

Observations 6, 7, and 8 about numbness and tingling did not change when workers with blanching and numbness and/or tingling were separated from workers with numbness and/or tingling only. When workers with blanching only were separated from workers with blanching and numbness and/or tingling, the patterns of finger blanching changed somewhat. Although the number of workers was small (10 workers), those with blanching only had a greater difference between the fingers of the chisel and throttle hands (e.g., 8 out of 10 workers had blanching on the tip of the middle finger on the chisel hand while only 3 out of 10 had blanching on the same location of the throttle hand).

Fourteen workers who reported blanching, numbness, or tingling used the chipping hammer in both their right and left hands. All of these workers were from the shipyard, and all reported using chipping hammers. Five of them had current job titles of pneumatic tool operator, five were chipper and grinder workers, three were propeller finishers, and one was a Boiler Maker. In some ways their fingers were affected differently by the three symptoms compared to other workers in the exposed group (see Table 22). Their index fingers and especially thumbs were highly affected by numbness, tingling, and blanching; however, they seemed to favor the left hand on the chisel (i.e., right handedness) because their left hands were more affected by blanching while the right hand was more affected by numbness and tingling.

When a worker responded positively to having symptoms of tingling, numbness or blanching of the fingers, he was asked if the symptoms occurred in cool or cold weather or in warm weather. Cold exposure is a stimulus to attacks of VWF and its symptoms. The occurrence of symptoms in warm weather would indicate a greater severity of the disease. Although respondents were asked

to choose between cold or warm weather, it is safe to assume that those answering yes to warm weather also experienced symptoms in cold weather. Respondents who said they had symptoms in both warm and cold weather were combined with those answering yes to occurrence in warm weather. Table 23 gives the number and percent with symptoms in cold or warm weather by stage of VWF for the exposed group. As the VWF stage increases in severity for all three symptoms the proportion having symptoms in warm weather increases. This relationship of cold and warm weather to VWF staging was found to be statistically significant for all three symptoms by Kendall's Tau-B measure of association (69). Kendall's Tau-B measure was 0.161 for tingling ($p = 0.025$), 0.176 for numbness ($p = 0.021$) and 0.291 for blanching ($p = 0.005$). Because the populations for these three tests are not distinct (i.e., they partially overlap), the probability levels given are gross estimates.

Workers were also asked if they had trouble sleeping because of tingling or numbness in their hands or fingers. Table 24 gives the proportions answering positively to this question by VWF stages. This table also shows an increasing proportion of workers having trouble sleeping because of numbness and tingling with increasing stages of VWF. A trend test for proportions (70) was used to determine if a significant linear trend is present in these proportions. The chi-square statistic for trend was significant ($p = 0.0039$) and did not depart significantly from linearity ($p = 0.73$).

An important characteristic of the VWF problem in a population is the latency of the disease. Latency is determined as the time period from the beginning of exposure to hand-arm vibration to the onset of the symptoms of VWF. The onset year of tingling, numbness, and blanching was recorded on the study questionnaire for workers reporting these symptoms. For this study, the starting date for the earliest job using a pneumatic chipping hammer was designated the beginning of hand-arm vibration exposure. For all exposed workers, the current job was considered a chipping hammer job.

The month and year were identified for the starting and ending dates of jobs. For latency calculations, the 15th of the month was assigned to each of these dates as the starting or ending day. Both days and months had to be assigned to the onset date of symptoms. These were assigned by the following criteria:

1. June 30 (year of onset for tingling, numbness or blanching) was used as the onset date except when the year of the survey was the same as the onset year, or the starting date for the earliest job using a chipping hammer was later than June 30 of the onset year.

2. When the onset year of the symptom was the same as the year of the survey, the onset date was set in the month of the survey and 15 days before the middle date of the survey (the surveys extended over a number of weeks and occurred in January, February, April, and May).

3. When the starting date of the earliest job using a chipping hammer occurred later than June 30 of the onset year, the onset date was set as December 31 of the onset year.

These criteria were chosen for consistency and conservatism. Criteria 2 and 3 are conservative because they tend to make the latency longer. Tables 25 through 30 give adjusted and unadjusted latencies of tingling, numbness, and blanching for exposed workers at the foundries and shipyard. Unadjusted latencies are the full-time period from the starting date for the earliest job involving the use of a chipping hammer to the onset date of the symptom. Adjusted latencies, calculated differently, are adjusted for the periods of time during the unadjusted latency period when the worker was not employed or worked on jobs where he did not use a chipping hammer.

The degree of adjustment required for each VWF stage group is summarized in Table 31. The VWF stage of 03 had the highest proportion of workers who had some jobs where they did not use chipping hammers. Two shipyard workers at VWF stage 03 had very long periods when they did not use chipping hammers and these workers contributed greatly to the large number of mean years when workers in stage 03 did not use chipping tools before the onset of numbness and blanching. (The tingling onset dates for these two workers were missing.) The wide disparity for stage 03 between mean and median years when chipping tools were not used is due to these two outliers. Stage ON also had a relatively higher proportion of workers not on chipping jobs for long periods before the onset date of numbness. For most symptoms and stage combinations, the mean and median latencies were closer after adjustment because of the reduction of outlying high latencies. Latencies in the low end of the range were almost unchanged by adjustment. The adjustment had the most dramatic effect (as would be expected from the data in Table 31) on the latency of numbness for stage ON workers at the foundries, latency of numbness for stages 01, 02, and 03 at the shipyard, and blanching latency for stage 03 at the shipyard.

The mean and median latencies of tingling were less than those of numbness and these were both less than the latencies for blanching within both the foundry and shipyard populations. The shipyard had much longer average latencies for all three symptoms than the foundries. On the average, workers at the foundries had acquired symptoms of VWF within 2 years while workers at the shipyard required at least 13 years for all symptoms to occur. At the shipyard, the median latencies were much less than the means. Fifty percent of workers with blanching at the shipyard had blanching within 9 years. At the foundries 50 percent of the workers had blanching within 1 year and 5 months.

As a measure of VWF risk, the latency of a symptom is not as dependent on the length of time a population has been exposed to hand-arm vibration as the prevalence of VWF stages. The latency for blanching is usually longer than the latency for tingling and numbness.

Two populations with similar exposure characteristics could have disparate prevalences of VWF cases at stages 01, 02, 03, and 04 but similar latencies of blanching because the population with the lower prevalence had less

exposure time. In examining two populations the prevalences of all stages and the latencies of all symptoms must be compared with the exposure times of VWF stage groups.

Figures 4 through 6 graphically present the unadjusted latencies for tingling, numbness, and blanching. These figures show the graphs of the cumulative percent of workers with these symptoms over time. The graphs for all three symptoms at the foundries appear to show an expotential increase in the percent of workers who acquired VWF symptoms (among those who had the symptoms) with increasing exposure time to vibration from chipping hammers. For the shipyard, the graphs seem to resemble linear increases in the percent of workers with symptoms over time, but the slopes appear to be very steep up to a cumulative 30% of workers and less so from 30% to 100%.

The median latencies may have been much less than the mean latencies for these symptoms because of the steep increases in workers affected up to the 50% point. The median may be a more meaningful measure of latency than the mean where these types of increases are observed.

HEALTH-RELATED VARIABLES AND VWF STAGING

Certain symptoms of pain and aching in the arms and hands, off-the-job disability and social impairment have been thought to be related to VWF. Seventeen questions (see Table 32) were asked on the study questionnaire about these symptoms and types of impairment. The relationship of both the occurrence of tingling, numbness and blanching and VWF staging to the responses to these questions was investigated.

The workers in the exposed group were grouped in Table 33 by combinations of the occurrence of tingling, numbness, blanching and stage of blanching. None of these groups overlap. Because the number of workers in some of these groups was very small they were recombined into symptom categories as shown in Table 34.

Table 34 gives the percentage of workers in each symptom category who answered yes to each of the 17 questions listed in Table 32. The following observations can be made baseed on the data in Table 34:

1. The proportion of workers in the control group (CO) answering yes to all of the questions was less than or equal to the proportion in the exposed group at stage 00 (EO).

2. The proportion of workers in the exposed group at stage 00 (EO) answering yes to all of the questions was less than or equal to the proportion with tingling, numbness, or blanching. This was the case except for the question concerning pain and aching in the shoulder, trouble sleeping because of tingling and numbness (BL group only), and difficulty distinguishing between hot and cold objects (BL and NB groups only).

3. A higher percentage of workers experiencing only tingling (T) or only tingling and blanching (TB) reported aching in the fingers than did those in all of the other symptom categories.

4. Workers experiencing tingling only (T) had a higher or equal percentage of yes answers to 12 of the 17 questions compared with those with numbness only (N).

5. Workers with tingling and numbness only (TN) had unexpectedly high percentages of yes answers compared with some of the workers with stages 01 and 02 blanching (BL, TB, NB, and 1B). Workers with tingling and numbness only (TN) exceeded at least one of these blanching groups (BL, TB, NB and 1B) for every question and exceeded all four blanching groups for 7 of the 17 questions. Workers with tingling, numbness, and stage 01 blanching had a lower

percentage of yes answers to 9 of the 17 questions compared with workers with tingling and numbness only (TN).

6. Among workers with tingling, numbness and blanching (1B, 2B, and 3B) the percentage of yes answers increased from 1B to 2B to 3B for 9 of the 17 questions. For the other 8 questions, 1B, 2B, and 3B had similar percentages of yes answers.

7. The question regarding aching in the fingers had the highest percentage of yes answers for 8 of the 10 exposed groups (i.e., E0 through 3B) and the next to highest for the other two exposed groups.

Tables 35 through 37 show the percentage of yes answers to these 17 questions by VWF stages. The questions have been separated into three logical groups:

1. Questions about pain and aching in the arms and hands.

2. Questions about difficulty doing things.

3. Questions about pain, tingling or numbness while performing activities.

The chi-square statistic for homogeneity, trend, and linearity (70) was calculated for the proportions of yes and no answers for each of these 17 questions by VWF stage (as shown in Tables 35 through 37). The number of yes answers to questions about pain, tingling, and numbness while swimming or gardening were too few to do a meaningful analysis. For the remaining 15 questions, the chi-square test for homogeneity and trend were significant at the 99% level (except for pain and aching in the shoulder, which was significant at the 98% level). Not all of the trends in the proportions were linear. In the responses to the following questions, proportions by VWF stage did not depart significantly from linearity: pain in the hand; pain and aching in the shoulder; difficulty doing fine work; difficulty handling coins; difficulty distinguishing hot and cold objects; pain, tingling, and numbness (PTN) while traveling to work; PTN while watching sports outdoors; and PTN while doing other hobbies. Because answers to these questions are not necessarily independent, significance tests are gross estimates. A multivariate analysis seemed unduly elaborate for these questions since the proportions in Tables 35 through 37 speak for themselves.

Other health-related factors are thought to be associated with VWF. Information about two of these factors, tobacco smoking and alcoholic beverage consumption, was asked on the questionnaire. Tobacco smoking was hypothesized to be associated with VWF because nicotine is a vasoconstrictor, and alcohol consumption was hypothesized as related because alcohol is a vasodialator.

Tables 38 and 39 show tobacco smoking and alcoholic beverage drinking habits of exposed and control workers by VWF staging. Both past and present (i.e., at the time of the survey) tobacco smoking habits were asked on the

questionnaire, but only present consumption of alcoholic beverages was asked. Statistical tests for association of the two factors (both separately and in various combinations) to VWF staging did not show any significant relationships. Although the control group of workers under 25 years of age had significantly fewer smokers than the exposed group of the same age group, there was no association between smoking and VWF stage groups among the exposed population. For alcoholic beverage consumption, the levels of drinking were almost identical among the control and exposed group and VWF stage groups.

The occurrence of most diseases is associated in some way with age. Date of birth was ascertained for each worker in the study population. Tables 40 through 43 characterize the ages of the population by exposure, medical, and industry groups. The exposed group from the foundries was much younger than the exposed group from the shipyard, while the reverse was true of the control group (see Tables 40 through 42). When industries are combined, the exposed and control groups have similar age distributions (see Table 42). The workers excluded for medical reasons were in general older (see Table 43) because many of the medical conditions that confound a diagnosis of VWF are diseases of older age.

Statistical tests of association did not reveal any relationships between age and occurrence or stage of VWF. This result is expected since the data show that exposed foundry workers were relatively young and had a high prevalence and short latency for VWF. Control workers spanned all age groups and none had VWF. Even among shipyard workers, age had no significant effect on the probability of having VWF. Exposure to hand-arm vibration remains the primary factor associated with VWF. The length of time exposed and the type of exposure will be discussed in the next section.

EXPOSURE VARIABLES AND VWF STAGING

The results presented in the section "VWF Staging and Latency" clearly showed a highly significant association between use of chipping and grinding tools on the job and vibration white finger disease. This chapter will address the relationships between time and intensity of exposure to hand-arm vibration from chipping and grinding tools and severity of VWF.

For workers in the exposed group, the number of years that chipping hammers were used on the job was calculated. The starting and ending dates and tool codes (see Table 8) recorded for each job were used to calculate the total number of years that chipping hammers were used on the job. Part-time jobs added half the number of years as full-time jobs. The current jobs of the exposed workers were always included in this calculation.

Tables 44 and 45 give the mean, median, and range of years for jobs requiring the use of chipping hammers by VWF stage for the foundry and shipyard industries. The shipyard workers had been employed on jobs using chipping hammers much longer than the foundry workers. This is consistent with the older age of the shipyard population. In both industries, the average length of time that chipping hammers were used increases with the increasing severity of the VWF stage. The significance of this relationship was tested using Kendall's Tau-B measure of association (69). This statistic tests for the association between two ordinal variables. The Kendall's Tau-B test results are given in Tables 46 and 47. Categories used in these tables were formed because they maximized cell size. For both the foundry and shipyard populations, the positive relationship between years on jobs using chipping hammers and severity of VWF stage was highly significant.

In the foundry population, the workers without VWF (stage 00) had a relatively long mean exposure time (i.e., years on jobs using chipping hammers). This result was due to the contribution of 3 workers (out of the 25 workers in stage 00) who had more than 12 years experience using a chipping hammer on jobs. The presence of these outliers in this stage group is reflected in the relatively short median exposure time of 1 year.

The median and mean exposure times for foundry workers in stages OT, ON, and TN did not differ considerably. Exposure times first increased at the blanching stages of 01, 02, and 03. In the shipyard population and for the VWF stages of TN, 01, 02, and 03, the length of exposures to chipping hammers was similar and actually decreased somewhat at stages 02 and 03. This decrease was due to two workers in stage 03 who reported more years on jobs using only grinding tools than years using a chipping hammer. Based on the logistic multiple regression model (71) the years on jobs using vibrating hand tools other than chipping hammers was found not to contribute

significantly to the exposure time to the chipping hammer and VWF stage model.

The relationship of current job title to VWF stage for workers in the exposed group was also investigated. As with exposure time, this variable had to be looked at separately for the foundry and shipyard industries because of the differences in job title descriptions and work designations. For the shipyard population, no significant differences resulted when the current job title was compared with VWF stages (see Table 48). In Table 48, job titles and VWF stages have been categorized because of the small numbers in cells.

The results for the foundries were very significant (see Table 49). The proportion of workers whose current job title was casting salvage, decreased as the severity of the VWF stage increased. The casting salvage group had a high percentage of workers in stage 00 compared with the other job title groups. The proportion of workers in the chip/grind-heavy and chip/grind group increased as the severity of the VWF stage increased. A similar pattern was found for workers in the chip intricate group, who had the highest percentage of workers in the severest VWF stages (i.e., 02 and 03). This association of current job title to VWF stage for the foundry population was highly statistically significant (see Table 50). Exposure time did not contribute to this association between current job title and VWF stage.

Casting salvage workers are an hourly paid group who clean imperfect castings. They are paid on an hourly basis because the imperfect castings are difficult and time-consuming to clean. Each imperfect casting requires a different method to bring it to an acceptable standard. The workers in the other three groups (chip/grind-heavy, chip/grind, and chip intricate) are paid on a piece-work basis. These workers have an incentive to work fast and clean a large number of castings. At both foundries, workers did not tend to change job title groups within the cleaning department. In addition, chipping and grinding workers at the foundries were usually new, young employees who trained into one of the chipping/grinding job title groups and stayed there until they could progress to a different department because of increased seniority.

Table 51 shows the distribution of exposed workers according to shift and industry. A cursory look at the foundries indicates an association between shift and VWF stage. As Table 52 illustrates, however, the relationship is due almost entirely to the unbalanced distribution of job title groups by shift. Two-thirds of the chip intricate group are on the day shift, while the other two job title groups are about evenly divided between day (or first) shift and second (or swing) shift (only 6% of foundry workers were not on first or second shift). For each shift group, the percentage of workers by job title and VWF stage categories is essentially the same.

Other occupational variables such as glove usage and position while working were unrelated to VWF staging. For glove usage especially, the percentage of workers not wearing gloves was very small (see Table 53). Additionally, no workers were found who had worked with vinyl chloride (another cause of white finger) on previous jobs to an extent to warrant special analyses.

MEDICAL EXAMINATION VARIABLES AND VWF STAGING

The study team physicians used much of the information recorded from the medical examinations (see Appendix C, Medical Coding Sheet) to determine if a worker should be medically excluded (see section on "Differential Diagnosis"). Only a few of the medical examination variables were intended for statistical analysis. These variables include certain digit conditions such as cyanosis, finger tip ulcers, joint swellings, knuckle pads, finger swellings, and calluses; wrist and finger mobility; and certain health disorders such as arthritis, Dupuytren's contracture, carpal tunnel syndrome, and tendonitis.

Results of associations between digit conditions and VWF staging are given in Tables 54 through 58. The number of workers with cyanosis and fingertip ulcers was too small for a meaningful analysis. The results for the other digit conditions were summarized for all fingers on each hand. The fingers on the dominant hands of the control workers were grouped together for analyses with the throttle fingers of the exposed workers and the opposite for chisel fingers (see section on "VWF Staging and Latency," Tables 19 through 22 for explanation of chisel and throttle hands). These analyses did not include exposed workers who used both hands on the chisel and control workers who were ambidexterous.

The number of workers with joint swellings on chisel fingers, knuckle pads on chisel and throttle fingers, and calluses on chisel and throttle fingers increased significantly with the increasing severity of VWF staging. Table 58, however, shows that some of these associations were due primarily to relationships between some of these digit conditions and the number of years that a chipping hammer was used. Especially in regard to calluses on chisel and throttle fingers the significant association of years using chipping hammers to both VWF staging and calluses indicates that calluses acquired from tool use cannot be separated statistically from those linked solely to VWF (see section on "Raynaud's Phenomenon of Occupational Origin, Secondary Complications").

For joint swellings on the chisel fingers and knuckle pads on the throttle fingers, there was no association of these digit conditions to years using chipping hammers. In other words, the proportion of workers with joint swellings on chisel fingers and knuckle pads on throttle fingers was unchanged whether the worker had shorter or longer periods of chipping hammer tool usage. On the throttle hand, the majority of the knuckle pads were located on the throttle index finger. No fingers on the chisel hand had a predominant proportion of joint swellings.

Tables 59 and 60 present the results of wrist and finger mobility and the health disorders mentioned at the beginning of this section. No significant

differences between the control and exposed groups were found in regard to abnormal wrist and finger mobility. Among workers not medically excluded, the number with these health disorders was too small to do any statistical analyses. When workers medically excluded were included in this analysis, the numbers still remained too small.

TEMPERATURE, PAIN, AND LIGHT-TOUCH SENSORY TESTS

Temperature, pain, and light-touch sensory tests were performed on each worker. The methods used to perform these three tests are given in the section, "Methods: Medical-Clinical Testing." Before these tests were performed, the skin temperature of the fingertips, webs, and palms were measured. If the skin temperatures were abnormal (below 85°F) and the hands could not be warmed, the sensory tests were considered invalid. Twenty-one workers in the control and exposed groups had abnormal skin temperatures and their sensory test results were excluded.

In each of the three tests, a normal or abnormal response for each finger was recorded. This gave 30 (3 tests times 10 fingers) test results for each worker. The results for the 10 fingers were summarized (by the physician who performed the sensory test) into one result for each test according to the following criteria:

1. If the subject had only normal responses for the digits of both hands, the subject was determined to be normal for that test.

2. If the subject had one or more abnormal responses, the subject was determined to be abnormal for that test except when all the abnormal responses could be attributed to medical causes such as scars or lacerations (then the subject was determined to be normal).

The number of workers in each VWF stage who had any possible combination of normal and abnormal responses to the sensory tests is given in Table 61. The control group had normal responses to all three tests except for one worker (this worker tested abnormal to temperature sensing). Ninety percent of the workers with blanching (VWF stages 01, 02, and 03) tested abnormal to the temperature or pain test (an abnormal response to the light-touch test always accompanied an abnormal response to one of the other two tests in this group).

On a population basis, the association between sensory test results and VWF stage was highly significant as measured by both the chi-square test ($p < 0.001$) and the lambda measure of proportional reduction in error ($p < 0.001$) (70). On an individual basis, though, these tests do not accurately predict the VWF stage of a worker. This is due primarily to the contradictory results for workers in stages OT, ON, and TN. These workers had 42% who were normal to all three tests, with the rest abnormal for at least one of the three tests (40% of this group were abnormal on both the temperature and pain test).

The results shown in Tables 62 and 63 demonstrate that the light-touch test added very little information and may somewhat confuse the interpretation of

results for these sensory tests. Of the 60 workers who were abnormal for the light-touch test, 93% were abnormal also for the temperature and/or pain test. Of the four workers who were abnormal for the light-touch test only, three of these workers were in stage 00 of the exposed group. All of the control group workers had normal responses to the light-touch test. The workers in VWF stage 01, 02, and 03, however, did much worse on this test than on the other two tests. Of the 72 workers in the blanching stages (VWF stages 01, 02, and 03) 58% showed normal response on the light-touch test. Tables 64 and 65 use two classification rules to show how well the results of the temperature and pain sensory tests can be used to classify workers into VWF stages. Table 64 divides workers into two groups: those without symptoms of tingling, numbness or blanching and those with one or more of these symptoms. This classification rule is best for correctly classifying workers who are normal to both tests as being in stage 00. The false negative rate is high (29%), however, and 81% of these false negatives were in the VWF stages of OT, ON, and TN.

The second classification rule (Table 65) uses the temperature and pain test results to classify workers into those without blanching symptoms and those with blanching symptoms. This classification is best for correctly classifying workers in stage 01, 02, and 03. The false positive rate is high (45%) however, 77% of these false positives were in the VWF stages of OT, ON, and TN. If the workers in these tingling and/or numbness stages are excluded from the analysis, the sensory tests would accurately predict the VWF stage of workers with or without blanching symptoms. This analysis is unrealistic, of course, because workers of all VWF stages can be present in a population.

SUMMARY AND CONCLUSIONS

1. A field survey of 385 workers at two foundries and a shipyard was carried out to study the health effects of workers using chipping and grinding tools on the job.

2. A decision model and selection criteria were designed to assign workers to exposure groups based on the use of vibrating hand tools on past and present jobs. Workers in the exposed group used pneumatic chipping and grinding tools on their present jobs and did not have confounding past exposures. Workers in the control group had never used vibrating hand tools on any jobs and did not have confounding hobby tool exposures.

3. Extensive medical histories and examination data from the survey were used to determine if workers had medical conditions that would confound a diagnosis of VWF (Vibration White Finger Disease). Thirteen percent of the exposed group and 12% of the control group had confounding medical conditions. Only 2.6% of the entire survey population had Primary Raynaud's Disease. Workers with confounding medical conditions were excluded from further analysis.

4. The prevalence of VWF in the exposed group was 47% at the foundries and 19% at the shipyard. None of the workers in the control group had symptoms of Raynaud's Phenomenon or white finger; control workers who had confounding medical conditions were excluded from the group.

5. The VWF diagnoses made by the survey physicians were compared for consistency with the VWF stages derived from the questionnaire data . Only seven inconsistencies were found, all of which were explicable according to medical or questionnaire information.

6. Surveys were made of the finger segments affected by the VWF symptoms of tingling, numbness, and blanching. The tip of the middle finger on each hand was affected in the highest proportion of workers, while the proximal segment of the thumb was least affected by all three symptoms.

7. The proportion of workers reporting tingling, numbness, or blanching in warm weather increased significantly with an increase in the severity of VWF stages. Also, the proportion of workers who had trouble sleeping because of numbness and tingling increased significantly with the increased severity of VWF stages.

8. The mean, median, and range of latencies for each symptom (tingling, numbness and blanching) were presented according to VWF stage and industry. Latencies were adjusted for the years when workers did not use chipping hammer. Graphs of the cumulative percentage of workers at latency intervals (in years) indicated a sharp increase in workers acquiring VWF symptoms. This increase was up to the median point for foundry workers and up to the 30% point for shipyard workers. Based on this increase and the large gaps between mean and median latencies due to outliers, median latencies may be a more meaningful measure of VWF latencies.

9. The median latency (unadjusted) for blanching was 1.4 years among foundry workers and 16.5 years among shipyard workers. Latencies for tingling and numbness were less than those for blanching.

10. Workers were asked to respond to sets of questions about a) pain and aching in parts of the arms and hands, b) difficulty performing specified activities, and c) pain, tingling or numbness when performing certain activities. The percentage of workers responding positively to these set of questions showed a statisticaly significant increase as severity of VWF stage increased.

11. No association was found between VWF stages and tobacco smoking, alcoholic consumption habits, or age.

12. The age distribution of the exposed and control groups was very similar, although age did not show any relationship to acquisition of VWF.

13. The severity of the VWF stage (as measured by Kendall's Tau-B measure of association) increased significantly in proportion to the number of years that the foundry and shipyard workers used chipping hammers on the job. Therefore, exposure time to pneumatic chipping and grinding tools was a significant risk factor for VWF in the populations surveyed.

14. For foundry workers a significant association was found between current job title and VWF stage. The job title group with the greatest proportion in stage 00 (without VWF) worked on an hourly basis, while the job title group with the greatest proportion in stages 02 and 03 (the most severe stages) included only piece workers.

15. Of the six digit conditions recorded, only joint swellings on the chisel hand and knuckle pads on the throttle hand were significantly associated to VWF without also being associated to exposure time.

16. Sensory tests for temperature, pain, and light-touch were significantly associated to VWF stages on a population basis, but did not distinguish well on an individual basis because of the results for the VWF stages of OT, ON, and TN.

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Table 1. Differential diagnosis--Raynaud's Phenomenon

Primary:	
1. Raynaud's Disease	Constitutional white finger
Secondary:	
1. Connective Tissue Disease	a. Scleroderma b. Systemic lupus erythematosus c. Rheumatoid arthritis d. Dermatomyositis e. Polyarteritis nodosa f. Mixed connective tissue disease
2. Trauma i. Direct to extremities	a. Following injury, fracture, or operation b. Of occupational origin (vibration) c. Frostbite and immersion syndrome
ii. To proximal vessels by compression	a. Thoracic outlet syndrome (cervical rib, scalenus anterior muscle) b. Costoclavicular and hyper-abduction syndromes
3. Occlusive Vascular Disease	a. Thromboangiitis obliterans b. Arteriosclerosis c. Embolism d. Thrombosis
4. Dysglobulinaemia	a. Cold haemagglutination syndrome - Cryoglobulinaemia - Macroglobulinaemia
5. Intoxication	a. Acro-osteolysis b. Ergot c. Nicotine
6. Neurogenic	a. Poliomyelitis b. Syringomyelia c. Hemiplegia

Table 2. Stage assessment of Raynaud's Phenomenon.

Stage	Condition of digits	Work and social interference
00	No tingling, numbness, or blanching of digits	No complaints
OT	Intermittent tingling	No interference with activities
ON	Intermittent numbness	No interference with activities
TN	Intermittent tingling and numbness	No interference with activities
01	Blanching of one or more fingertips with or without tingling and numbness	No interference with activities
02	Blanching of fingers beyond tips. Usually confined to winter	Slight interference with home and social activities. No interference at work.
03	Extensive blanching of digits. Frequent episodes in summer as well as winter.	Definite interference at work, at home, and with social activites. Restriction of hobbies.
04	Extensive blanching. Most fingers. Frequent episodes in summer and winter.	Occupational change to avoid further vibration exposure because of severity of signs and symptoms.

NOTE: Complications are not used in this grading.

Figure 1. NIOSH Medical Trailer.

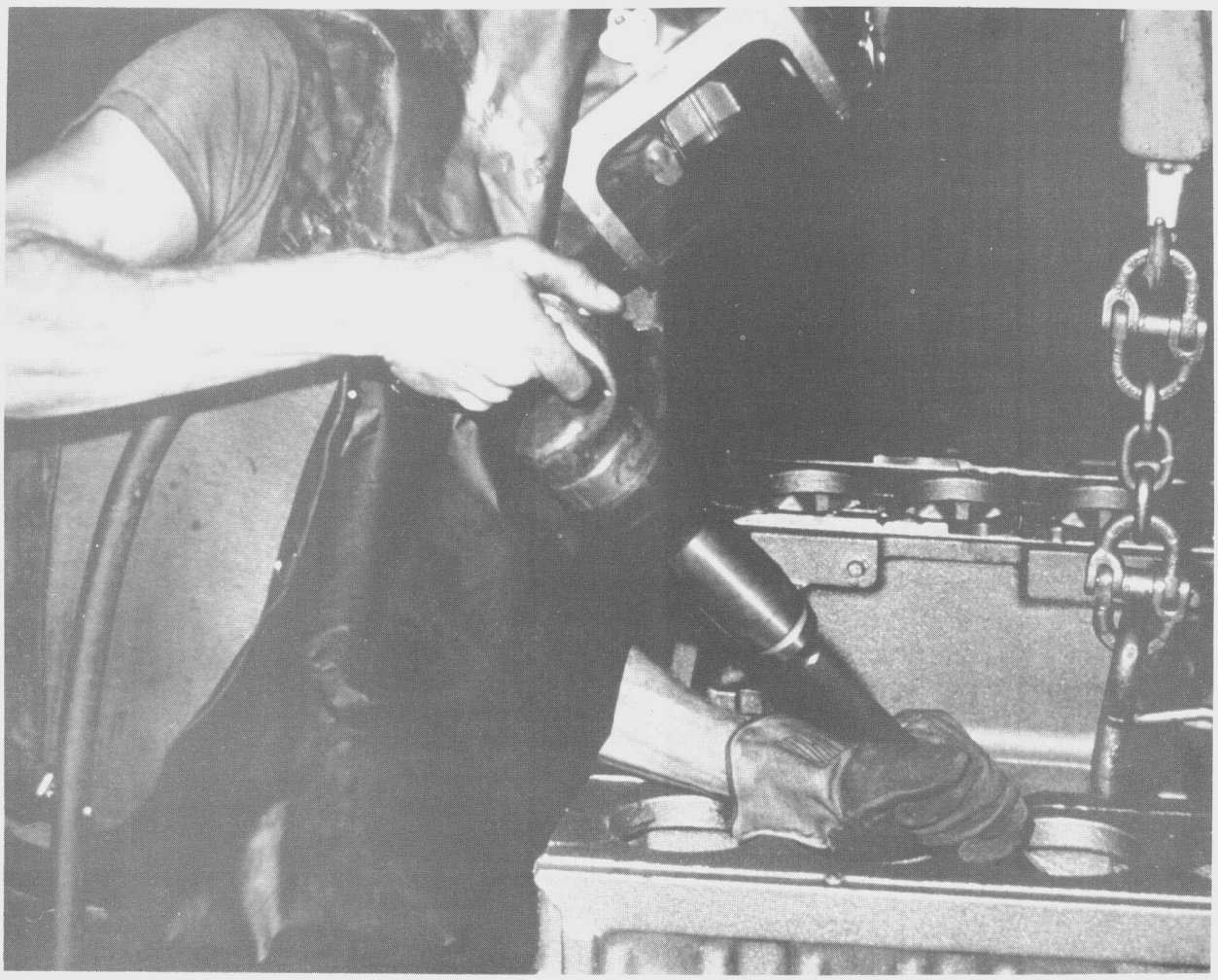


Figure 2. Foundry Worker Operating a Chipping Hammer.

Table 3. Information collected on each participant.

Present employer

1. Department number
2. Job Title
3. Starting date
4. Ending date
5. Full-time or part-time
6. Shift
7. Vibrating hand-tool types
8. Position: sitting and/or standing
9. Glove usage

Past employer

1. Name of past employer
2. Type of company
3. Starting date
4. Ending date
5. Full-time or part-time
6. Job title
7. Vinyl chloride exposure
8. Vibrating hand-tool types

Information collected for each hobby with a vibrating hand tool

1. Type of hobby
2. Vibrating hand-tool type
3. Starting date of hobby
4. Ending date of hobby

Table 4. Jobs with present and past employers.

	Number	Percent of total
Current jobs with present employers	385	56%
Past jobs with present employers	147	21%
Past jobs with past employers	160	23%
Total	692	100%

Table 5. Tools causing confounding exposure.

Jackhammer
Chain saw
Riveting hammer
Air tamper (as used in construction industries)
Bumble bee

Tool code descriptions for the above tools* (from Appendix D)

Air tampers
Chain saw
Electric impact drill; jackhammer
Electric saw; jackhammer
Jackhammer
Jackhammer; drill
Needle Guns; bumble bees; buffers
Riveting Hammer; drill
Saber saw; electric drill; chain saw
Tamper
Vibrators to pack ground
Jackhammer; OMC machinery

(*Tool Code Descriptions for these tools combined with Chipping Hammers are not shown - see Table 8 and the Description of Exposure Group 1.)

Table 6. Job titles excluded from the group of workers currently using chipping and grinding tools.

Job title (for current job)	Percentage of workers reporting use of chipping hammer on current job
Pneumatic supervisor	50% (1 of 2)
Pipe fitter	25% (1 of 4)
Test specialist	50% (1 of 2)

Table 7. Job titles of workers currently using chipping and grinding tools.

Job title (for current job)	Percentage of workers reporting Use of chipping hammers on current job
Boiler maker	100% (7/7)
Casting salvage	100% (28/28)
Chip and grind heavy	100% (42/42)
Chip intricate	98% (56/57)
Chip and grind	98% (58/59)
Propellor finisher	96% (24/25)
Pneumatic tool operator (PTO)	97% (30/31)
PTO test specialist	100% (7/7)
Reclaimer	100% (1/1)
Ship fitter	100% (1/1)
Tank specialist	100% (1/1)

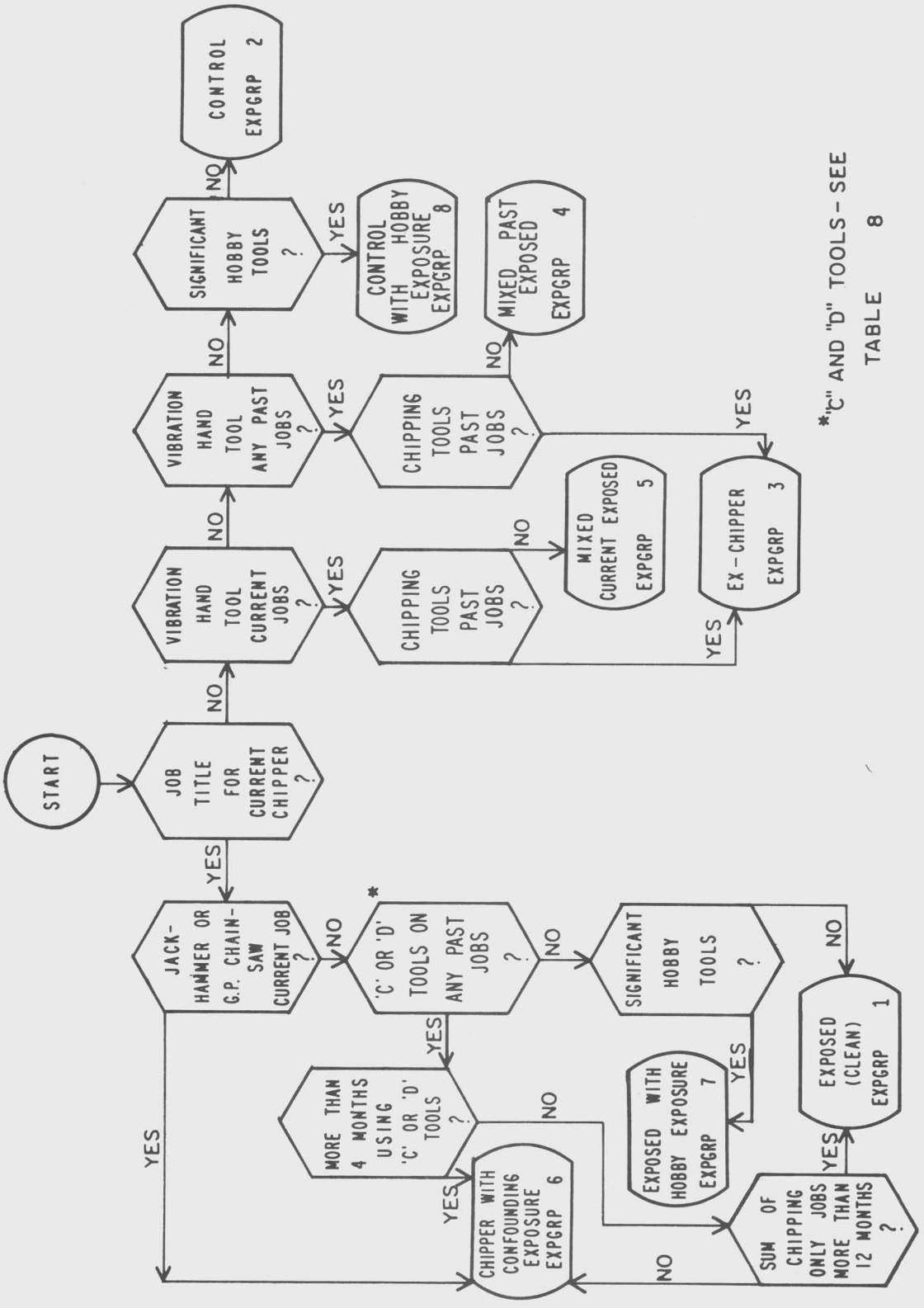


Figure 3. Decision diagram and selection criteria for exposure groups (expgrp).

Table 8. Tool categories referenced in Figure 3.

Tool category	
A	= Chipping hammers without jackhammers or gasoline-powered chain saws
B	= All tools except those in Categories A, C, and D (does not include hobby tools)
C	= Jackhammers, gasoline-powered chain saws, riveting hammers, air tampers and bumble bees without chipping hammers
D	= Jackhammers and gasoline-powered chain saws with chipping hammers
E	= Chain saws and chipping hammers used as hobby tools
F	= All hobby tools except for those in E
N	= No vibrating hand tool

Table 9. Number and Percentage of Workers in the Exposure Groups (column percents, c%).

Exposure group	Total	Foundries	Shipyard
Exposed group, expgrp 1	235 (61%)	159 (60%)	76 (62%)
Control group, expgrp 2	72 (19%)	51 (19%)	21 (17%)
Ex-chippers, expgrp 3	30 (8%)	23 (9%)	7 (6%)
Mixed past exposed, expgrp 4	13 (3%)	12 (5%)	1 (1%)
Mixed current exposed, expgrp 5	9 (2%)	0 (0%)	9 (7%)
Confounded chippers, expgrp 6	19 (5%)	11 (4%)	8 (7%)
Exposed with hobby exposure, expgrp 7	5 (1%)	5 (2%)	0 (0%)
Control with hobby exposure, expgrp 8	2 (1%)	2 (1%)	0 (0%)

Table 10. Medical Conditions of Secondary Raynaud's Phenomenon in the Study Population.

1. Carpal tunnel syndrome
2. Severe burn of digit(s)
3. Frostbite of digit(s)
4. Scleroderma of digit(s)
5. Laceration(s) of digit(s)
6. Extensive hand trauma
7. Crush injury to digit(s)
8. Severe clubbing of digit(s)
9. Operations on digit(s)
10. Severe arthritis
11. Mallet finger deformity
12. Hand deformity
13. Amputation of digit(s)
14. High blood pressure (hypertension)
15. Heart disease
16. Cardiovascular disease
17. Peripheral vascular disease
18. Diabetes
19. Parkinson's disease
20. Von Recklinghausen's disease

Table 11. Medical Exclusion Groups.

1. Hand or digit trauma or disease
2. High blood pressure
3. Special diseases
4. Mixed - more than one medical condition (except Primary Raynaud's Disease)
5. Primary Raynaud's Disease

Table 12. Frequency and Proportion of Workers in the Medical Exclusion Groups (column percents).

Medical exclusion group	Total population (N*=385)	Foundries (N=263)	Shipyard (N=122)
Hand/digit trauma/disease	11 (2.9%)	8 (3%)	3 (2.5%)
High blood pressure	11 (2.9%)	5 (1.9%)	6 (4.9%)
Special diseases	9 (2.3%)	6 (2.3%)	3 (2.5%)
Mixed diseases	11 (2.9%)	3 (1.1%)	8 (6.6%)
Primary Raynaud's disease	10 (2.6%)	7 (2.7%)	3 (2.5%)
All Medical Exclusions (Total)	52 (13.6%)	29 (11.0%)	23 (19.0%)

*N=number of workers

Table 13. Medical exclusions by exposure group--row percents (r%) and column percents (c%).

Exposure group	Medical Exclusion Group: No medical exclusion	Medical exclusion groups 1-4	Primary Raynaud's Disease	Total
Exposure Group 1 (exposed)	205 (87r%) (62c%)	27 (12r%) (64c%)	3 (1r%) (30c%)	235 (100r%) (61c%)
Exposure Group 2 (control)	63 (88r%) (19c%)	6 (8r%) (14c%)	3 (4r%) (30c%)	72 (100r%) (19c%)
Exposure Groups 3 through 8	65 (83r%) (19c%)	9 (12r%) (22c%)	4 (5r%) (40c%)	78 (100r%) (20c%)
Total	333 (86r%) (100c%)	42 (11r%) (100c%)	10 (3r%) (100c%)	385 (100r%) (100c%)

Table 14. White Finger (WF) staging of workers in medical exclusion groups (MEDGRP).

	WF Stage					
	Stage 00		Stages OT, ON, and TN		Stages 01, 02, and 03*	
Exposure Groups	Medgrps 1 Through 4	Primary Raynaud's	Medgrps 1 Through 4	Primary Raynaud's	Medgrps 1 Through 4	Primary Raynaud's
Exposed	6	0	13	0	8	3
Control	4	0	1	1	1	2
Exposure groups 3 through 8	5	0	1	0	3	4

* These groups had no stage 04 cases

Table 15. VWF staging by industry and exposure groups (medical exclusion groups not included).

Exposure Group	VWF Staging						
	00	OT	ON	TN	01	02	03 and 04
Exposed-Foundries, N=147	25	14	10	29	29	33	7
Exposed-Shipyard, N=58	21	6	10	10	5	3	3
Control-Foundries, N=42	42	-	-	-	-	-	-
Control-Shipyard, N=21	21	-	-	-	-	-	-
Ex-chippers-Foundries, N=18	9	0	1	2	1	4	1*
Ex-chippers-Shipyard, N=4	3	0	0	1	0	0	0
Mixed past exposed-Foundries, N=11	11	-	-	-	-	-	-
Mixed past exposed-Shipyard, N=1	-	1	-	-	-	-	-
Mixed current exposed-Foundries,N=0	-	-	-	-	-	-	-
Mixed current exposed-Shipyard,N=9	6	0	1	1	1	0	0
Confounded chipper-Foundries, N=10	1	3	2	3	1	0	0
Confounded chipper-Shipyard N=6	2	0	2	2	0	0	0
Exposed W/hobby-Foundries, N=5	2	0	0	1	1	1	0
Exposed W/hobby-Shipyard, N=0	-	-	-	-	-	-	-
Control W/hobby-Foundries, N=1	1	-	-	-	-	-	-
Control W/hobby-Shipyard, N=0	-	-	-	-	-	-	-
TOTAL N=333	144	24	26	49	38	41	11

* Only stage 04 case

Table 16. Prevalence of VWF in the exposed group* (row percents).

	VWF Staging		
	00	OT, ON and TN	01, 02, and 03
Exposed workers - Foundries N = 147	17%	36%	47%
Exposed workers - Shipyard N = 58	36%	45%	19%
Total N = 205	22%	39%	39%

* Medical Exclusion Groups not included.

Table 17. Consistency between VWF symptoms from questionnaire and clinical diagnosis of VWF. Medical exclusion cases omitted.

VWF Symptoms (from questionnaire)	VWF Staging (clinical diagnosis)							
	00	0T	0N	TN	01	02	03	04
No reported symptoms	141	0	1	1	0	0	0	0
Tingling only	1	24	0	1	0	0	0	0
Numbness only	0	0	25	0	0	0	0	0
Tingling and numbness	0	0	0	46	0	0	0	0
Blanched (white) fingers only	1	0	0	0	7	3	0	0
Blanched (white) fingers and tingling	0	0	0	0	11	6	0	0
Blanched (white) fingers and numbness	0	0	0	0	2	6	1	1
Blanched (white) fingers; tingling and numbness	0	0	0	0	18	26	9	0
Missing Data	1	0	0	1	0	0	0	0

Table 18. Workers with inconsistencies between VWF symptoms on questionnaire and VWF diagnosis.

1. A test specialist at the shipyard with a past history of using a chipping hammer (ex-chipper-EXPGRP 3). This worker answered yes to the question on the questionnaire concerning blanched fingers. The physicians recorded that he had only one attack of blanched fingers during World War II, when he was exposed to extreme cold while on guard duty in the army. Because he experienced no tingling or numbness, he was staged 00.

2. A propeller finisher at the shipyard with no past jobs involving the use of vibrating hand tools (exposed - EXPGRP1). This worker had a history of arthritis, was sensitive to the cold, and was on asthma medication. Although the physicians had recorded TN on the questionnaire, he answered no to the questions regarding tingling and numbness. The physicians reviewed this inconsistency and decided to accept the diagnosis, although no record was made of tingling and numbness for this worker.

3. A pneumatic tool operator at the shipyard (for 1 year) who had used a jackhammer at a pavement company for 10 years (confounded chipper - EXPGRP 6). Although this worker gave a negative response to the question concerning numbness, a medical examination and interview established that he had intermittant numbness . Thus, he was staged ON.

4. A core finisher at Foundry 1 with no history of using vibrating hand tools (control - EXPGRP 2). This worker answered yes to the question regarding tingling. During a medical review of his data, however, physicians noted that tingling had occurred in 1961 and had not reoccurred since then. He was staged 00.

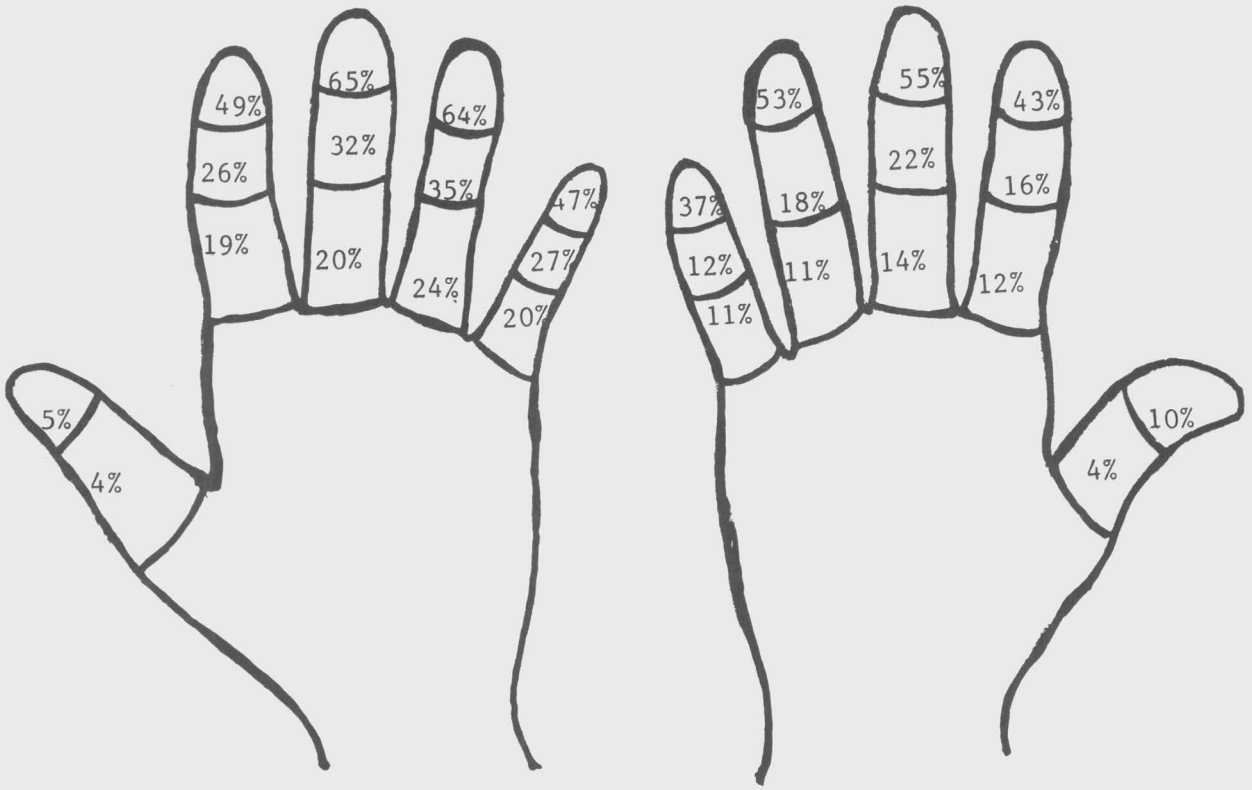
5. A chip intricate worker at Foundry 1 (for 1 year) with no past jobs involving the use of vibrating hand tools (exposed - EXPGRP 1). He answered yes to the tingling and numbness questions on the questionnaire but gave a "don't know" answer regarding finger blanching. The physicians recorded the same symptoms and a stage of TN.

6. A chipper/grinder at Foundry 1 (for 1 year) and no past jobs involving the use of vibrating hand tools (exposed - EXPGRP 1). Altnough this worker answered yes to tingling and no to numbness on the questionnaire, the physicians determined that he had numbness and tingling during exposure to cold (while snowmobile riding) he was staged TN.

7. A chip/grind, heavy worker at Foundry 1 with one past job involving the use of a pneumatic drill to install air conditioners (exposed EXPGRP 1). He answered "don't know" to all three symptoms on the questionnaire. The physicians recorded that he didn't have any symptoms of VWF and was staged 00.

Table 19. Blanching of finger segments.

Percent reporting blanching at each finger segment among all who reported blanching (exposed group only)(N = 80)



*Left hand for those using left hand on chisel, N = 70

*Right hand for those using right hand on chisel, N = 4

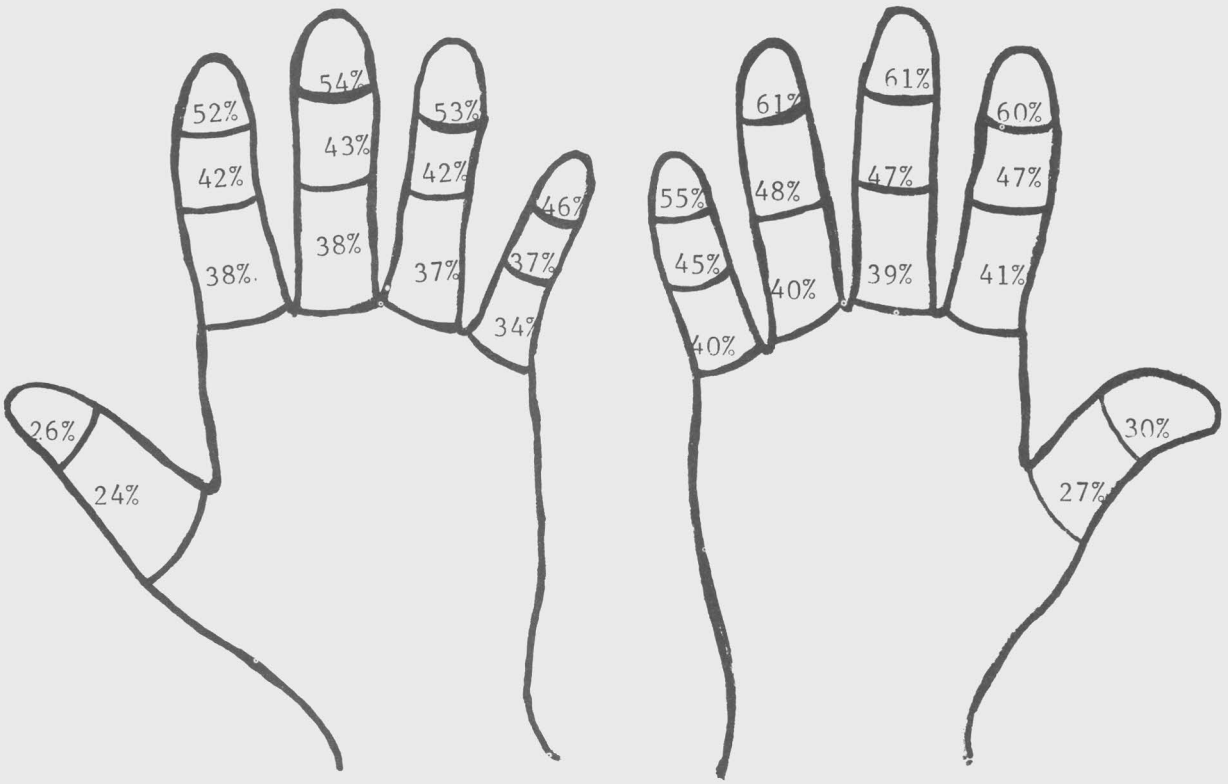
*Right hand for those using left hand on chisel, N = 70

*Left hand for those using right hand on chisel, N = 4

Two workers had missing data
Four workers had both hands on chisel (see Table 22)

Table 20. Numbness of finger segments.

Percent reporting numbness at each finger segment among all who reported numbness (exposed group only) (N = 111)



*Left hand for those using left hand on chisel, N = 90

*Right hand for those using right hand on chisel, N = 8

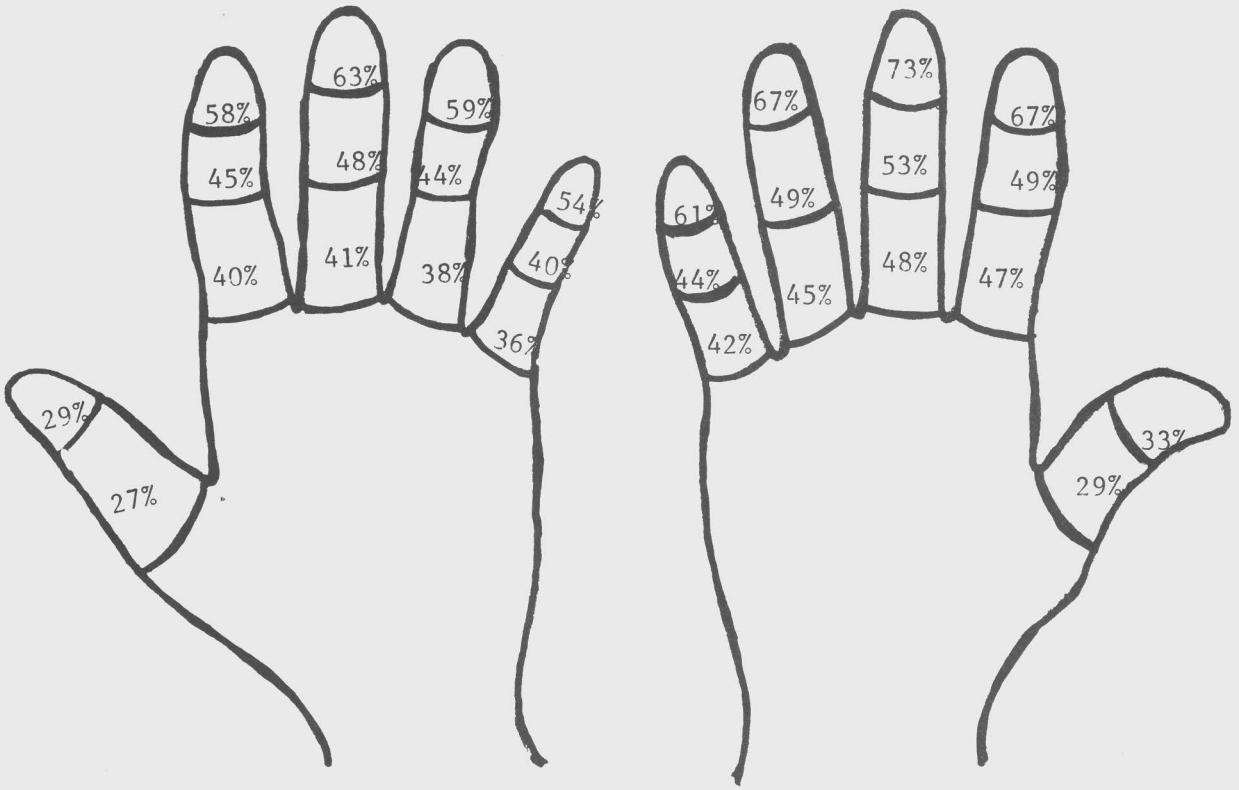
*Right hand for those using left hand on chisel, N = 90

*Left hand for those using right hand on chisel, N = 8

One worker had missing data
One worker had missing data for hand on chisel
Eleven workers had both hands on chisel (see Table 22)

Table 21. Tingling of finger segments.

Percent reporting tingling at each finger segment among all who reported tingling (exposed group only)(N = 120)



*Left hand for those using left hand on chisel, N = 104

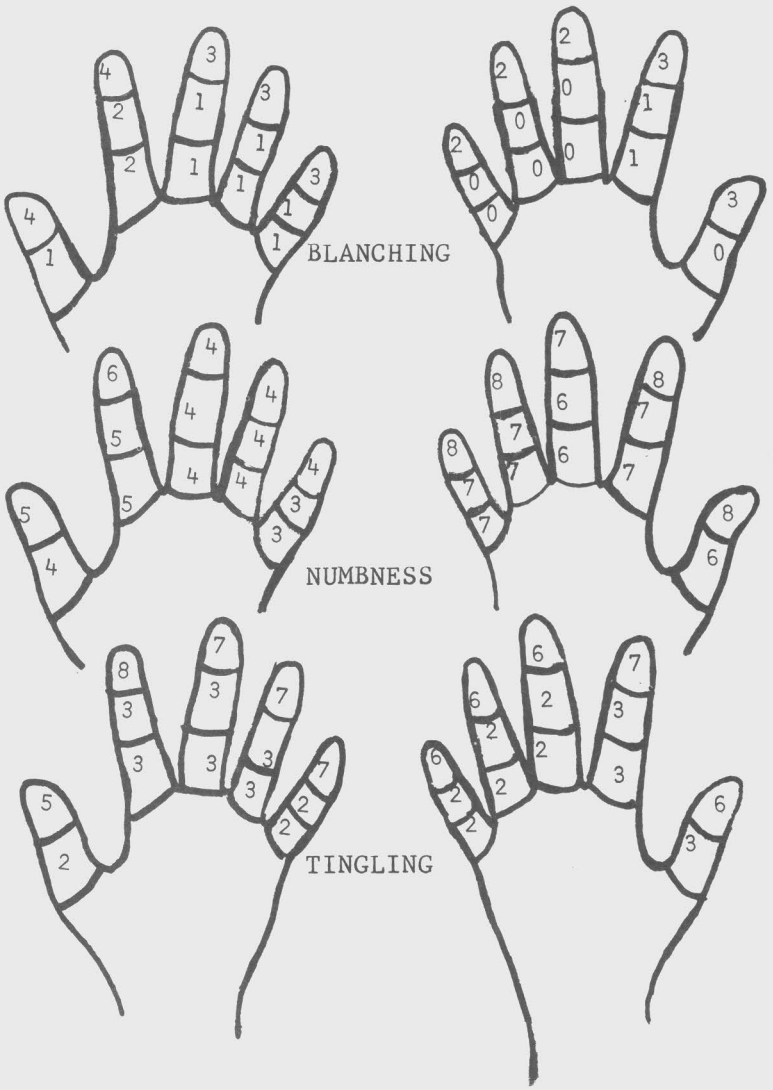
*Right hand for those using right hand on chisel, N = 6

*Right hand for those using left hand on chisel, N = 104

*Left hand for those using right hand on chisel, N = 6

One worker had missing data
Nine workers used both hands on chisel (see Table 22)

Table 22. Number of workers with symptoms at finger segments for workers using both hands on chisel (exposed group only) (N=14).



Number of workers reporting blanching at finger segments, N = 4

Number of workers reporting numbness at finger segments, N = 11

Number of workers reporting tingling at finger segments, N = 9

Table 23. Occurrence of tingling, numbness, and blanching in warm or cold weather (exposed group only, number ( ) and row percent).

TINGLING

VWF Stage	Cold/cool weather	Warm weather
OT	63% (12)	37% (7)
TN	47% (18)	53% (20)
01	52% (12)	48% (11)
02	37% (10)	63% (17)
03	25% (2)	75% (6)

5 = Don't know

NUMBNESS

VWF Stage	Cold/cool weather	Warm weather
ON	77% (13)	23% (4)
TN	43% (15)	57% (20)
01	44% (7)	56% (9)
02	44% (12)	56% (15)
03	30% (3)	70% (7)

6 = Don't know

BLANCHING

VWF Stage	Cold/Cool weather	Warm weather
01	94% (30)	6% (2)
02	79% (27)	21% (7)
03	56% (5)	44% (4)

4 = Don't know
1 = Missing data

Table 24. Workers who had trouble sleeping because of tingling and/or numbness in hands or fingers (exposed group only, number ( ) and row percents).

VWF Stage	NO	YES
OT	90% (18)	10% (2)
ON	95% (19)	5% (1)
TN	72% (28)	28% (11)
01	74% (25)	26% (9)
02	64% (23)	36% (13)
03	60% (6)	40% (4)

Table 25. Latencies of tingling for workers at the foundries (exposed group only). Latencies are adjusted and unadjusted for the number of years that workers did not use chipping hammers before the onset of tingling.*

VWF Stage	Adjusted latencies (in years)	Unadjusted latencies (in years)
OT (N = 13)		
Mean	0.7	0.9
Median	0.3	0.3
Range	0.1 - 2.8	0.1 - 2.8
TN (N = 27)		
Mean	0.9	1.8
Median	0.4	0.4
Range	0.1 - 4.5	0.1 - 16.7
01,02, and 03 (N=54)		
Mean	1.7	1.9
Median	0.8	0.8
Range	0.1 - 13.6	0.1 - 14.5
All stages (N = 94)		
Mean	1.3	1.8
Median	0.5	0.6
Range	0.1 - 13.6	0.1 - 16.7

*Data were missing for three workers.

Table 26. Latencies of tingling for workers at the shipyard (exposed group only). Latencies are adjusted and unadjusted for the number of years that workers did not use chipping hammers before the onset of tingling.*

VWF Stage	Adjusted latencies (in years)	Unadjusted latencies (in years)
OT (N = 6)		
Mean	4.9	5.1
Median	2.2	2.9
Range	0.2-14.9	0.2-14.9
TN (N = 9)		
Mean	9.3	9.8
Median	5.6	5.6
Range	0.04-26.6	0.04-30.7
01,02, and 03 (N = 6)		
Mean	12.2	12.2
Median	9.7	9.7
Range	0.04-30.9	0.04-30.9
All Stages (N = 21)		
Mean	8.9	9.1
Median	4.0	4.2
Range	0.04-30.9	0.04-30.9

*Data were missing for two workers.

Table 27. Latencies of numbness for workers at the foundries (exposed group only). Latencies are adjusted and unadjusted for the number of years that workers did not use a chipping hammers before the onset of numbness.*

VWF Stage	Adjusted latencies (in years)	Unadjusted latencies (in years)
ON (N = 9)		
Mean	1.8	4.5
Median	1.2	1.8
Range	0.1-6.4	0.1-22.3
TN (N = 27)		
Mean	0.9	1.8
Median	0.4	0.4
Range	0.1-4.5	0.1-16.7
01,02, and 03 (N = 44)		
Mean	1.8	2.0
Median	1.2	1.4
Range	0.04-13.6	0.04-14.5
All Stages (N = 80)		
Mean	1.5	2.2
Median	0.7	0.8
Range	0.04-13.6	0.04-22.3

*Data were missing for two workers.

Table 28. Latencies of numbness for workers at the shipyard (exposed group only). Latencies are adjusted and unadjusted for the number of years that workers did not use chipping hammers before the onset of numbness.*

VWF Stage	Adjusted latencies (in years)	Unadjusted latencies (in years)
ON (N = 8)		
Mean	7.9	8.1
Median	6.5	6.5
Range	0.08 - 18.9	0.08 - 20.9
TN (N = 9)		
Mean	9.3	9.8
Median	5.6	5.6
Range	0.04 - 26.6	0.04 - 30.7
01,02,and 03 (N = 9)		
Mean	13.2	17.8
Median	8.0	16.5
Range	0.7 - 31.0	0.7 - 38.9
All stages (N = 26)		
Mean	10.2	12.0
Median	6.8	9.5
Range	0.04 - 31.0	0.04 - 38.9

*Data were missing for three workers.

Table 29. Latencies of blanching for workers in the foundries (exposed group only). Latencies are adjusted and unadjusted for the number of years that workers did not use chipping hammers before the onset of blanching.

VWF Stage	Adjusted latencies (in years)	Unadjusted latencies (in years)
01 (N = 29)		
Mean	1.4	1.5
Median	0.8	0.8
Range	0.04 - 8.9	0.04 - 8.9
02 (N = 33)		
Mean	2.2	2.6
Median	1.7	1.7
Range	0.2 - 13.6	0.2 - 14.5
03 (N = 7)		
Mean	1.6	1.9
Median	1.3	1.5
Range	0.2 - 4.0	0.2 - 5.4
01,02, and 03(N = 69)		
Mean	1.8	2.0
Median	1.3	1.4
Range	0.04 - 13.6	0.04 - 14.5

Table 30. Latencies of blanching for workers in the shipyard (exposed group only). Latencies are adjusted and unadjusted for the number of years that workers did not use chipping hammers before the onset of blanching.

VWF Stage	Adjusted latencies (in years)	Unadjusted latencies (in years)
01 (N = 5)		
Mean	15.7	15.7
Median	16.5	16.5
Range	3.9 - 27.4	3.9 - 27.4
02 (N = 3)		
Mean	14.5	14.5
Median	8.0	8.0
Range	4.5 - 30.9	4.5 - 30.9
03 (N = 3)		
Mean	8.1	21.1
Median	4.5	23.9
Range	1.8 - 18.0	4.5 - 35.0
01,02, and 03(N = 11)		
Mean	13.3	16.8
Median	8.8	16.5
Range	1.8 - 30.9	3.9 - 35.0

Table 31. Years of work on jobs not involving the use of chipping hammers for workers with tingling, numbness, or blanching (exposed group only).

	VWF Stage					
	OT	ON	TN	01	02	03
Number of workers	4	5	6	3	7	7
Percentage of stage group	20%	25%	15%	9%	19%	70%
Mean years of work not involving the use of chipping hammer	6.6	6.3	5.0	0.9	1.7	6.4
Median years of work not involving the use of a chipping hammer	1.8	3.2	2.3	0.7	1.7	1.3
Range of work years not involving the use of a chipping hammer	1.3 21.3	1.0 21.4	.08 15.6	0.2 1.9	0.8 2.4	.04 33.2
Mean years of work without a chipping hammer before the onset of tingling	1.6 (N=2)	-	5.0 (N=6)	1.9 (N=1)	1.6 (N=4)	1.0 (N=2)
Mean years of work without a chipping hammer before the onset of numbness	-	9.0 (N=3)	5.0 (N=6)	1.9 (N=1)	1.5 (N=4)	10.7 (N=4)
Mean years of work without a chipping hammer before the onset of blanching	-	-	-	1.9 (N=1)	1.7 (N=7)	10.3 (N=4)

Figure 4.

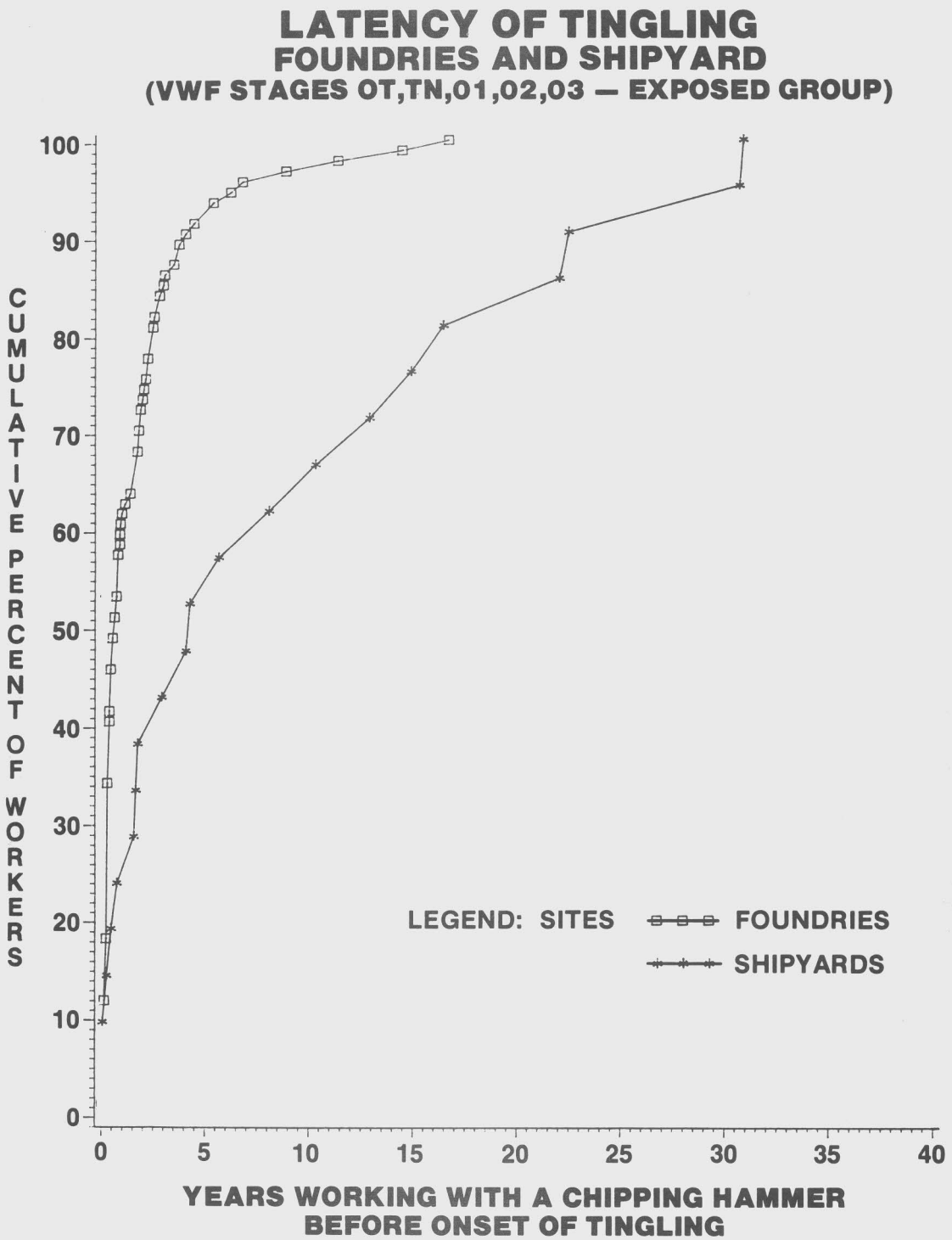

LATENCY OF TINGLING
FOUNDRIES AND SHIPYARD
(VWF STAGES OT,TN,01,02,03 — EXPOSED GROUP)
CUMULATIVE PERCENT OF WORKERS
100
90
80
70
60
50
40
30
20
10
0
0
5
10
15
20
25
30
35
40
YEARS WORKING WITH A CHIPPING HAMMER
BEFORE ONSET OF TINGLING
LEGEND: SITES
FOUNDRIES
SHIPYARDS

Figure 5.

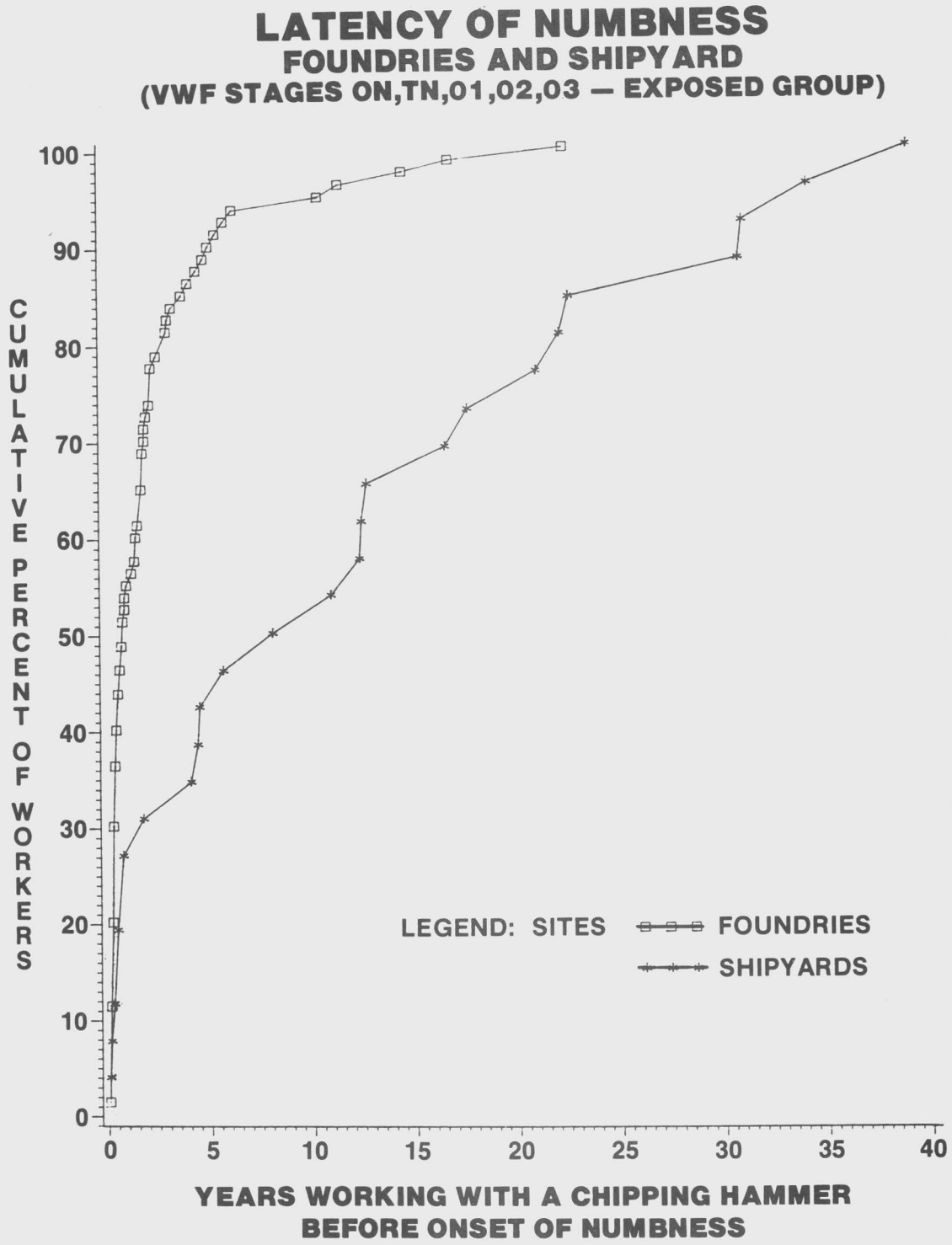

LATENCY OF NUMBNESS
FOUNDRIES AND SHIPYARD
(VWF STAGES ON,TN,01,02,03 — EXPOSED GROUP)
CUMULATIVE PERCENT OF WORKERS
100
90
80
70
60
50
40
30
20
10
0
0
5
10
15
20
25
30
35
40
YEARS WORKING WITH A CHIPPING HAMMER
BEFORE ONSET OF NUMBNESS
LEGEND: SITES
FOUNDRIES
SHIPYARDS

Figure 6.

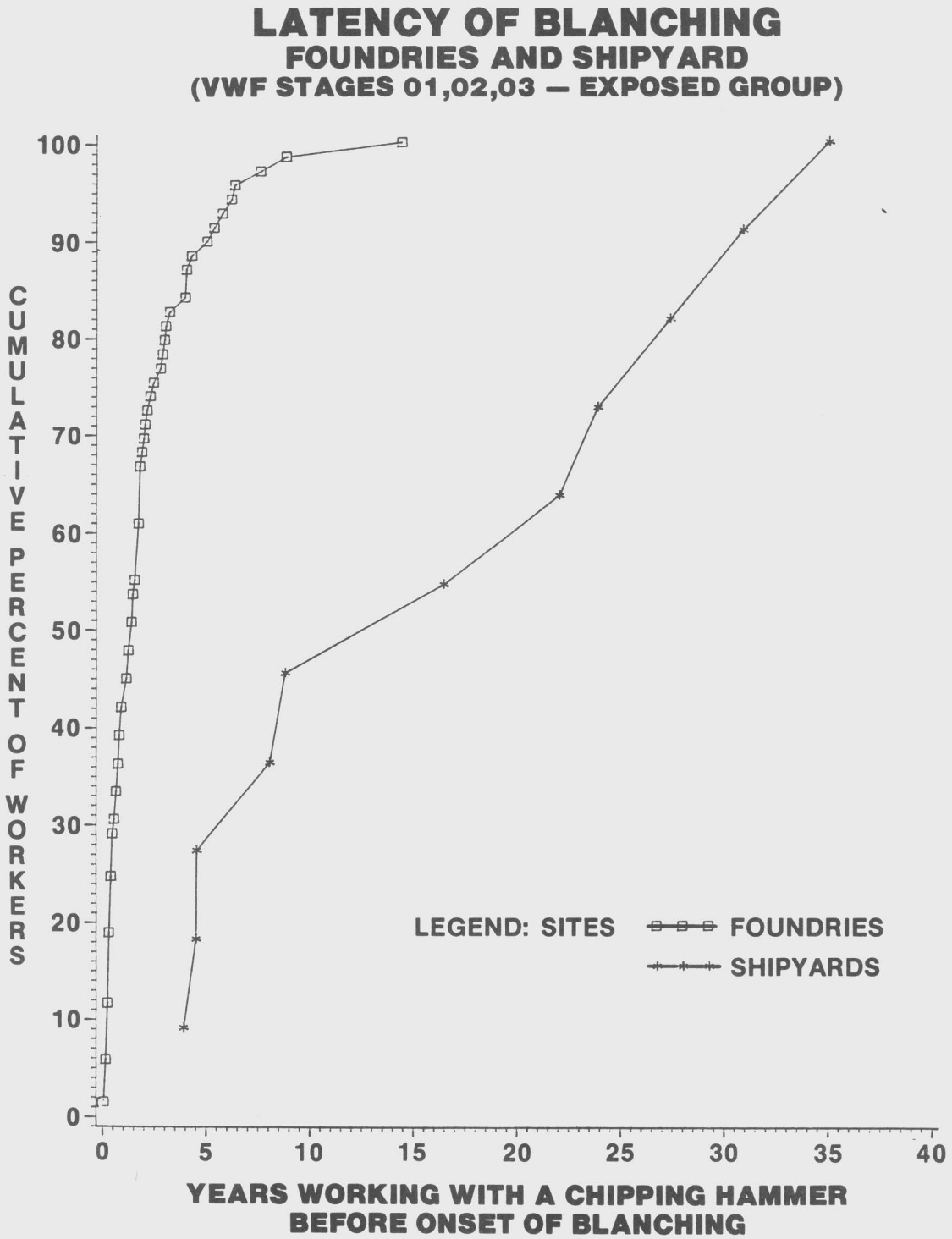

LATENCY OF BLANCHING
FOUNDRIES AND SHIPYARD
(VWF STAGES 01,02,03 — EXPOSED GROUP)
CUMULATIVE PERCENT OF WORKERS
100
90
80
70
60
50
40
30
20
10
0
0
5
10
15
20
25
30
35
40
YEARS WORKING WITH A CHIPPING HAMMER
BEFORE ONSET OF BLANCHING
LEGEND: SITES
FOUNDRIES
SHIPYARDS

Table 32. Questionnaire Responses - Row Symbols.

Have you had trouble sleeping because of numbness or tingling in your hands or fingers?	TRSL
Do you ever have aching in your fingers?	AF
What about pain in your hands?	PH
Do you ever have pain or aching in any of the following parts of your body?	
wrists	WPA
elbows	EPA
shoulders	SPA
Do you have difficulty doing any of the following activities?	
doing fine work	DFW
fastening buttons	DFB
handling or picking up coins	DHC
distinguishing between hot and cold objects	DDHC

Do you have pain, tingling or numbness in your hands or fingers when you do any of the following things?

traveling to work	TNTW
swimming	TNS
gardening	TNG
washing your car	TNWC
watching sports outdoors	TNWS
playing games	TNPG
doing other hobbies	TNOH

Table 33. Distribution of exposed workers by tingling, numbness, and blanching symptoms combined (from study questionnaire; exposed group only).*

Tingling	Numbness	Blanching	Blanching Stage	VWF Stage	Number	%
No	No	No	00	00	46	23
Yes	No	No	00	0T	21	10
No	Yes	No	00	0N	20	10
Yes	Yes	No	00	TN	37	18
No	No	Yes	01	01	7	3
Yes	No	Yes	01	01	11	5
No	Yes	Yes	01	01	2	1
Yes	Yes	Yes	01	01	14	7
No	No	Yes	02	02	3	1
Yes	No	Yes	02	02	5	3
No	Yes	Yes	02	02	5	3
Yes	Yes	Yes	02	02	23	11
No	No	Yes	03	03	0	0
Yes	No	Yes	03	03	0	0
No	Yes	Yes	03	03	1	0.5
Yes	Yes	Yes	03	03	9	4

*Data was missing for one worker

Table 34. Percentage of "yes" responses to questions about symptoms

	CO	EO	T	N	TN	BL	TB	NB	1B	2B	3B
TRSL	0%	4%	9%	5%	30%	0%	25%	29%	43%	44%	40%
AF	0%	26%	62%	35%	70%	50%	75%	43%	64%	61%	60%
PH	0%	9%	38%	15%	57%	10%	56%	29%	64%	44%	60%
WPA	8%	13%	19%	25%	62%	50%	37%	14%	57%	52%	60%
EPA	8%	9%	24%	10%	46%	30%	31%	0%	21%	52%	60%
SPA	8%	33%	19%	45%	27%	0%	37%	29%	43%	30%	40%
DFW	3%	9%	19%	15%	23%	30%	31%	43%	21%	48%	60%
DFB	2%	4%	5%	0%	24%	20%	6%	0%	14%	44%	50%
DHC	0%	9%	9%	20%	27%	40%	19%	29%	29%	44%	50%
DDHC	2%	2%	19%	10%	16%	0%	25%	0%	29%	26%	30%
TNTW	0%	2%	19%	15%	38%	20%	44%	29%	50%	65%	60%
TNS	0%	0%	0%	0%	0%	0%	0%	0%	0%	4%	10%
TNG	0%	0%	0%	10%	16%	0%	0%	0%	7%	13%	40%
TNWC	0%	6%	9%	5%	39%	10%	12%	14%	14%	52%	60%
TNWS	0%	2%	14%	5%	16%	20%	12%	29%	36%	26%	50%
TNPG	0%	0%	14%	5%	32%	10%	12%	14%	14%	39%	50%
TNOH	2%	4%	9%	10%	28%	20%	19%	0%	14%	39%	50%

Explanation of column and row symbols.*

Symptom Categories	Column Symbols
No symptoms - control	CO
No symptoms - exposed	EO
Tingling only	T
Numbness only	N
Tingling and numbness only	TN
Blanching only (Stages 01 & 02)	BL
Tingling only and blanching (Stages 01 and 02)	TB
Numbness only and blanching (Stages 01 and 02)	NB
Tingling, numbness, and blanching (Stage 01)	1B
Tingling, numbness, and blanching (Stage 02)	2B
Tingling and/or numbness and blanching (stage 03)	3B

*Explanation of Row Symbols given in Table 32.

Table 35. Percentage of yes answers to questions about pain and aching in parts of the arm and hand. (see Table 32 for legend of row symbols).

	00 (control) N=63	00 (exposed) N=46	VWF Stage 0T N=20	0N N=20	TN N=39	01 N=34	02 N=36	03 N=10
AF	0%	26%	60%	35%	69%	56%	67%	60%
PH	0%	9%	40%	15%	54%	41%	47%	60%
WPA	8%	13%	20%	25%	59%	41%	50%	60%
EPA	8%	9%	25%	10%	44%	18%	47%	60%
SPA	8%	33%	20%	45%	26%	32%	28%	40%

Table 36. Percentage of yes answers to questions about difficulty performing activities (see Table 32 for legend of row symbols).

	00 (control) N=63	00 (exposed) N=46	VWF Stage 0T N=20	0N N=20	TN N=39	01 N=34	02 N=36	03 N=10
DFW	3%	9%	20%	15%	21%	21%	50%	60%
DFB	2%	4%	5%	0%	23%	9%	33%	50%
DHC	0%	9%	10%	20%	26%	23%	42%	50%
DDHC	2%	2%	20%	10%	15%	21%	19%	30%

Table 37. Percentage of yes answers to questions about pain, tingling, or numbness during activities (see Table 32 for legend of row symbols).

	VWF Stage							
	00 (control) N=63	00 (exposed) N=46	0T N=20	0N N=20	TN N=39	01 N=34	02 N=36	03 N=10
TNTW	0%	2%	20%	15%	36%	32%	61%	60%
TNS	0%	0%	0%	0%	0%	0%	3%	10%
TNG	0%	0%	0%	10%	15%	3%	8%	40%
TNWC	0%	6%	10%	5%	36%	9%	42%	60%
TNWS	0%	2%	15%	5%	15%	23%	25%	50%
TNPG	0%	0%	15%	5%	31%	12%	31%	50%
TNOH	2%	4%	10%	10%	26%	12%	33%	50%

Table 38. Number and percentage (column) of workers in tobacco smoking categories, by VWF stages

Smoking Categories	VWF Stage 00 (control)	00 (exposed)	OT	ON	TN	01	02	03
Nonsmoker	23 (36%)	11 (24%)	6 (30%)	3 (15%)	11 (28%)	10 (29%)	9 (25%)	1 (10%)
Ex-smoker	20 (32%)	11 (24%)	4 (20%)	3 (15%)	7 (18%)	2 (6%)	4 (11%)	3 (30%)
Moderate cigarette smoker	6 (9%)	11 (24%)	1 (5%)	6 (30%)	4 (10%)	7 (21%)	12 (33%)	1 (10%)
Heavy cigarette smoker	13 (21%)	12 (26%)	9 (45%)	6 (30%)	16 (41%)	14 (41%)	9 (25%)	4 (40%)
Moderate pipe or cigar smoker	1 (2%)	0	0	2 (10%)	1 (3%)	1 (3%)	1 (3%)	0
Heavy pipe or cigar smoker	0	0	0	0	0	0	0	0
Missing or invalid data for smoking history	0	1 (2%)	0	0	0	0	1 (3%)	1 (10%)
TOTAL (COLUMN)	63 (100%)	46 (100%)	20 (100%)	20 (100%)	39 (100%)	34 (100%)	36 (100%)	10 (100%)

Table 38 continued

Definitions of tobacco smoking categories

Nonsmoker	Does not currently smoke cigarettes, cigars, or pipes and has never smoked or inhaled them.
Ex-smoker	Does not currently smoke cigarettes, cigars, or pipes but has formerly smoked and inhaled them.
Moderate cigarette smoker	Currently smokes less than a pack a day.
Heavy cigarette smoker	Currently smokes a pack or more a day.
Moderate cigar or pipe smoker	Currently smokes cigars or pipes but does not inhale them; has never smoked or inhaled cigarettes.
Heavy cigar or pipe smoker	Currently smokes and inhales cigars or pipes; has never smoked or inhaled cigarettes.

Table 39. Alcoholic beverage consumption.

	VWF Stage							
	00 (controls)	00 (exposed)	OT	ON	TN	01	02	03
Number of workers who never drink or were not drinking at the time of the survey.	9	12	2	5	8	8	5	3
Number of workers who drank at the time of the survey.	54	34	18	15	31	26	31	7
Mean ounces of alcoholic beverages drank monthly.*	45	51	51	60	59	75	41	37

* Calculated from the number of cans or bottles of beer usually drank weekly, bottles of wine drank monthly, and cocktails or other liquor drinks consumed weekly.

Table 40. Mean, median, and range of ages by exposure group and industry.

Exposure group and industry	Age		
	Mean	Median	Range
Exposed-foundries	26	24	20-49
Exposed-shipyard	41	42	22-66
Control-foundries	34	30	21-63
Control-shipyard	25	25	21-30
Ex-chippers-foundries	30	28	21-43
Ex-chippers-shipyard	43	43	29-59
Mixed past exposed-foundries	37	38	20-62
Mixed past exposed-shipyard	28	28	28
Mixed current exposed-shipyard	31	26	23-53
Confounded chipper-foundries	26	23	20-42
Confounded chipper-shipyard	51	52	30-63
Exposed w/hobby-foundries	25	24	22-29
Control w/hobby-foundries	28	28	28

TABLE 41

Percentage of Exposed and Control Workers in Age Groups

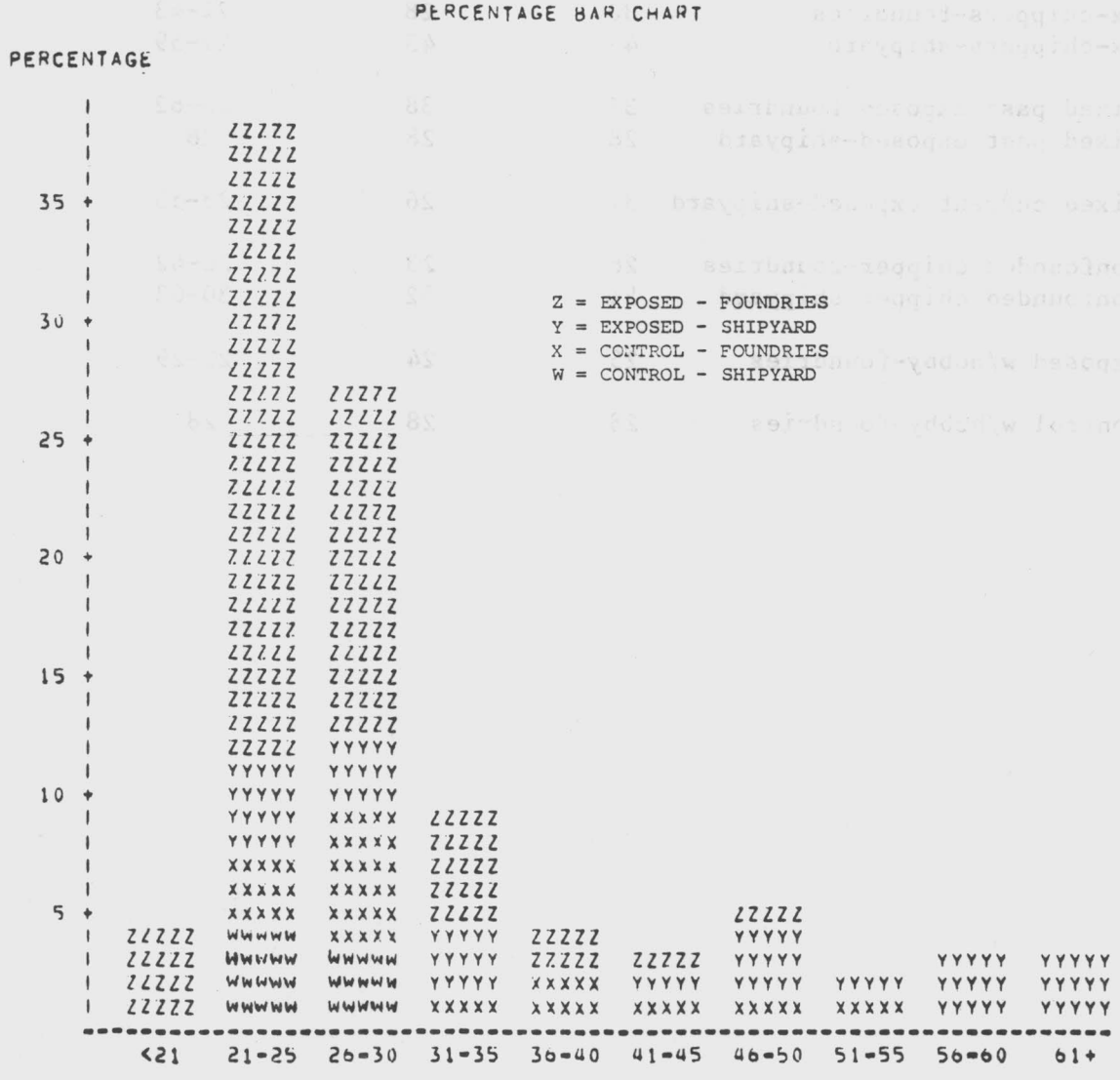


Table 42. Ages of exposed group and control group (industries combined).

	Exposed	Control
Mean age	30 years	31 years
Median age	27 years	28 years
Range of ages	20-66 years	21-63 years
(Number of Workers)	(205)	(63)

Table 43. Mean ages of workers in medical exclusion groups (all exposure groups combined).

	Mean ages	
Medical exclusion groups	Foundries	Shipyard
Hand/digit trauma	36 (22-55)	49 (26-60)
High blood pressure	36 (23-49)	49 (30-58)
Special diseases	38 (25-59)	56 (52-59)
Mixed diseases (except Primary Raynaud's Disease)	44 (24-59)	59 (55-63)
Primary Raynaud's Disease	34 (22-50)	40 (32-53)
All medical exclusion groups	37 = Mean 42 = Median (22-59)	52 = Mean 56 = Median (26-63)

Table 44. Years on jobs using a chipping hammer for foundry workers by VWF stage.

	VWF Stage						
	00 N=25	OT N=14	ON N=10	TN N=29	01 N=29	02 N=33	03 N=7
Mean years on jobs using a chipping hammer	3.2	1.6	2.2	1.5	2.6	4.0	4.9
Median years on jobs using a chipping hammer	1.0	0.9	1.6	1.1	2.4	4.0	4.6
Range of years on jobs using a chipping hammer	0.2 to 14.5	0.2 to 4.4	0.2 to 7.0	0.2 to 5.0	0.5 to 9.5	0.8 to 18.2	1.9 to 9.9

Table 45. Years on jobs using a chipping hammer for shipyard workers by VWF stage.

	VWF Stage					
	00 N=21	OT N=6	ON N=10	TN N=10	01 N=5	02 and 03 N=6
Mean years on jobs using a chipping hammer	7.6	9.0	10.6	19.6	18.1	16.8
Median years on jobs using a chipping hammer	5.6	8.3	8.2	17.9	17.3	9.1
Range of years on jobs using a chipping hammer	0.1 to 27.9	2.4 to 16.7	0.1 to 27.2	4.4 to 41.9	4.7 to 33.4	3.6 to 38.9

Table 46. Number (column percent) of foundry workers in exposure categories (years on jobs using a chipping nammer) and VWF stage categories.

Exposure category (years on jobs using a chipping hammer)	VWF stage category				Row total
	00	OT, ON & TN	01	02 & 03	
Less than or = 1.5 years	14(56%)	32(60%)	13(45%)	7(17.5%)	66
Greater than 1.5 but less than or = 3.0 years	3(12%)	14(27%)	5(17%)	7(17.5%)	29
Greater than 3.0 years	8(32%)	7(13%)	11(38%)	26(65%)	52
Column totals	25(100%)	53(100%)	29(100%)	40(100%)	147

Chi-square value: 29.8, 6 D.F., p less than 0.00001
Kendall's Tau-B value 0.31, p less than 0.0001

Table 47. Number (column percents) of shipyard workers in exposure categories (years on jobs using a chipping hammer) and VWF stage categories.

Exposure category (years on jobs using a chipping hammer)	VWF Stage Category			Row Total
	00	OT & ON	TN,01,02&03	
Less than or = 5.0 years	10 (47%)	7 (44%)	5 (24%)	22
Greater than 5.0 but less than or = 15.0 years	9 (43%)	3 (19%)	5 (24%)	17
Greater than 15.0 years	2 (10%)	6 (37%)	11(52%)	19
Column totals	21 (100%)	16(100%)	21(100%)	58

Chi-square value: 9.9, 4 D.F., p = 0.041
Kendall's Tau-B value: 0.29, p = 0.002

Table 48. Current job titles of shipyard workers (exposed group); row percents shown.

	VWF Stage Category		
	00	OT & ON	TN,01,02&03
Boiler maker	3 43%	2 28.5%	2 28.5%
Chip and grind	2 22%	4 45%	3 33%
Propeller finisher	6 35%	5 30%	6 35%
Pneumatic tool operator (PTO) and PTO test specialist and Ship Fitter	10 40%	5 20%	10 40%

Table 49. Current job titles of foundry workers (exposed group); row percents shown.

	VWF Stage						
	00	0T	ON	TN	01	02	03
Casting salvage and reclaimer	10 40%	4 16%	3 12%	1 4%	4 16%	3 12%	0 0
Chip and grind, heavy	6 19%	2 6%	3 9%	8 25%	7 22%	5 16%	1 3%
Chip and grind	5 12%	5 12%	2 5%	13 32%	7 17%	7 17%	2 5%
Chip intricate	4 8%	3 6%	2 4%	7 14%	11 23%	18 37%	4 8%

Table 50. Number (column percents) of foundry workers in current job title categories and VWF stage categories (exposed group).

	VWF Stage Category			
	00	OT&ON	TN&01	02&03
Casting salvage and reclaimer	10 (40%)	7 (29%)	5 (9%)	3 (8%)
Chip and grind, heavy and chip and grind	11 (44%)	12 (50%)	35 (60%)	15 (37%)
Chip intricate	4 (16%)	5 (21%)	18 (31%)	22 (55%)

Chi-square value: 26.2, 6 D.F., p = 0.0002
Kendall's Tau-B value: 0.33, p less than 0.0001

Table 51. Distribution of exposed workers according to shift and industry.

Foundries

Shift at current job	Percent on shift
7-3 pm	58%
3-11 pm	36%
11-7 am	3%
Rotate	3%

Shipyard

Shift at current job	Percent on shift
7-3 pm	81%
3-11 pm	16%
11-7 am	0%
Rotate	3%

Table 52. Current job titles for all foundry shifts(row percents).

	VWF Stage		
Day shift	00,0T,0N	TN,01,02,03	Row totals
Casting salvage and reclaimer	9 75%	3 25%	12 100%
Chip and grind, heavy, and chip and grind	13 32.5%	27 67.5%	40 100%
Chip intricate	6 18%	27 82%	33 100%
All other shifts	00,0T,0N	TN,01,02,03	Row totals
Casting salvage and reclaimer	8 62%	5 38%	13 100%
Chip and grind, heavy, and chip and grind	10 30%	23 70%	33 100%
Chip intricate	3 19%	13 81%	16 100%

Table 53. Glove usage and position by industry (for exposed group).

Usage of gloves while working with vibrating hand tools (current job)

	Foundries	Shipyard
Yes	98%	97%
No	2%	3%

Usual position while working (current job)

	Foundries	Shipyard
Sitting	1%	0%
Standing	99%	69%
Both sitting and standing	0%	31%

Table 54. Presence of joint swellings on chisel and throttle fingers (row percents).

VWF Stage	Chisel Fingers or Fingers on Non-Dominant Hand		Throttle Fingers or Fingers on Dominant Hand	
	Joint Swellings		Joint Swellings	
	Absent	Present	Absent	Present
00 (control) N = 57	56 98%	1 2%	53 93%	4 7%
00 (exposed) N = 34	30 88%	4 12%	29 85%	5 15%
OT and ON N = 33	27 82%	6 18%	28 85%	5 15%
TN N = 35	28 80%	7 20%	30 86%	5 14%
01 N = 32	23 72%	9 28%	27 84%	5 16%
02 and 03 N = 44	35 79%	9 21%	35 80%	9 20%
	Chi-square value = 14.2 5 D.F. p = 0.015 Kendall's Tau-B value = 0.19, p less than 0.0001		Chi-square value = 3.9 5 D.F. p = 0.56 Kendall's Tau-B value = 0.10 p less than 0.05	

Table 55. Presence of knuckle pads on chisel and throttle fingers (row percents).

VWF Stage	Chisel Fingers or Fingers on Non-Dominant Hand		Throttle Fingers or Fingers on Dominant Hand	
	Knuckle Pads Absent	Present	Knuckle Pads Absent	Present
OO (control) N = 57	50 88%	7 12%	48 84%	9 16%
OO (exposed) N = 34	23 68%	11 32%	28 82%	6 18%
OT and ON N = 33	21 64%	12 36%	26 79%	7 21%
TN N = 35	18 51%	17 49%	19 54%	16 46%
01 N = 32	22 69%	10 31%	22 69%	10 31%
02 and 03 N = 44	24 55%	20 45%	31 70%	13 30%
	Chi-square value = 18.3 5 D.F. p = 0.003 Kendall's Tau B value = 0.20, p less than 0.0001		Chi-square value = 12.5 5 D.F. p = 0.028 Kendall's Tau-B value = 0.14, p less than 0.02	

Table 56. Presence of finger swellings on chisel and throttle fingers (row percents).

VWF Stage	Chisel Fingers or Fingers on Non-Dominant Hand		Throttle Fingers or Fingers on Dominant Hand	
	Finger Swellings Absent	Present	Finger Swellings Absent	Present
00 (control) N = 57	54 95%	3 5%	57 100%	0 0%
00 (exposed) N = 34	31 91%	3 9%	33 97%	1 3%
OT and ON N = 33	28 85%	5 15%	29 88%	4 12%
TN N = 35	31 89%	4 11%	31 89%	4 11%
01 N = 32	26 81%	6 19%	30 94%	2 6%
02 and 03 N = 44	38 86%	6 14%	40 91%	4 9%
	Chi-square value = 4.7 5 D.F. p = 0.45 Kendall's Tau-B value = 0.10, p less than 0.05		Chi-square value = 8.4 5 D.F. p = 0.14 Kendall's Tau-B value = 0.12, p less than 0.02	

Table 57. Presence of calluses on chisel and throttle fingers (row percents).

VWF Stage	Chisel Fingers or Fingers on Non-Dominant Hand: Calluses Absent	Chisel Fingers or Fingers on Non-Dominant Hand: Calluses Present	Throttle Fingers or Fingers on Dominant Hand: Calluses Absent	Throttle Fingers or Fingers on Dominant Hand: Calluses Present
00 (control)	39	18	34	23
N = 57	68%	32%	60%	40%
00 (exposed)	23	11	15	19
N = 34	68%	32%	44%	56%
OT and ON	20	13	13	20
N = 33	61%	39%	39%	61%
TN	13	22	11	24
N = 35	37%	63%	31%	69%
01	12	20	7	25
N = 32	37%	63%	22%	78%
02 and 03	15	29	9	35
N = 44	34%	66%	20%	80%

Chi-square value = 21.9
5 D.F. p = 0.0005
Kendall's Tau-B value
= 0.25, p less than 0.0001

Chi-square value = 21.8
5 D.F. p = 0.0006
Kendall's Tau-B value
= 0.27, p less than 0.0001

Table 58. Relationship between joint swellings, knuckle pads, or calluses and years working on jobs using a chipping hammer (row percents).

	Chisel Fingers		Throttle Fingers
	Joint Swellings		
	Absent	Present	
Less than 1.5 years at foundries or less than 10.0 years at shipyard	(67) 80%	(17) 20%	(Joint swellings on throttle fingers not significant.)
Greater than 1.5 years at foundries or greater than 10.0 years at shipyard	(76) 81%	(18) 19%	

Chi-square prob. = 0.86

	Knuckle pads		Knuckle pads	
	Absent	Present	Absent	Present
Less than 1.5 years at foundries or less than 10.0 years at shipyard	(57) 68%	(27) 32%	(62) 74%	(22) 26%
Greater than 1.5 years at foundries or greater than 10.0 years at shipyard	(51) 54%	(43) 46%	(64) 68%	(30) 32%
	Chi-square prob. = 0.064		Chi-square prob. = 0.40	

	Calluses		Calluses	
	Absent	Present	Absent	Present
Less than 1.5 years at foundries or less than 10.0 years at shipyard	(45) 54%	(39) 46%	(35) 42%	(49) 58%
Greater than 1.5 years at foundries or greater than 10.0 years at shipyard	(38) 40%	(56) 60%	(20) 21%	(74) 79%
	Chi-square prob. = 0.079		Chi-square Prob. = 0.003	

Table 59. Wrist and finger mobility for exposed and control groups (row percents).

	Wrist flexion	
	Normal	Abnormal
Control	94%	6%
Exposed	97%	3%

	Wrist extension	
	Normal	Abnormal
Control	95%	5%
Exposed	98%	2%

	Finger flexion	
	Normal	Abnormal
Control	87%	13%
Exposed	86%	14%

	Finger extension	
	Normal	Abnormal
Control	92%	8%
Exposed	88%	12%

Table 60. Arthritis, Dupuytren's contracture, carpal tunnel syndrome, and tendonitis in exposed and control workers (not including medical exclusion cases; row percents).

	Arthritis	
	Absent	Present
Control	95%	5%
Exposed	97%	3%

	Dupuytren's contracture	
	Absent	Present
Control	100%	0%
Exposed	99%	1%

	Carpal tunnel syndrome	
	Absent	Present
Control	100%	0%
Exposed	99%	1%

	Tendonitis	
	Absent	Present
Control	98%	2%
Exposed	95%	5%

Table 61. Combined responses of workers to the three sensory tests.

Sensory Tests						VWF Stage				
Temperature	Pain	Light-Touch	00 (control)	00 (exposed)	OT	ON	TN	01	02	03
N	N	N	60	28	11	8	11	3	4	0
N	N	A	0	3	0	1	0	0	0	0
N	A	N	0	1	2	0	1	2	3	0
A	N	N	1	4	1	0	3	7	1	0
N	A	A	0	1	0	0	4	0	0	0
A	N	A	0	1	0	0	1	2	4	1
A	A	N	0	1	2	5	10	11	5	2
A	A	A	0	3	2	4	6	7	14	6
			61	42	18	18	36	32	31	9

Note: Twenty-one workers were excluded because of abnormal skin temperatures.

Table 62. Percentage of workers in each VWF stage with zero to three abnormal responses on the temperature, pain, and light-touch tests (column percents).

	VWF Stage							
	00 (control)	00 (exposed)	OT	ON	TN	01	02	03
All normal responses	98%	67%	61%	44%	31%	9%	13%	0%
One Abnormal response	2%	19%	17%	6%	11%	28%	13%	0%
Two Abnormal responses	0%	7%	11%	28%	41%	41%	29%	33%
Three Abnormal responses	0%	7%	11%	22%	17%	22%	45%	67%

Table 63. Percentage of workers in each VWF stage with zero to two abnormal responses on temperature and pain tests (column percents).

	VWF Stage							
	00 (control)	00 (exposed)	OT	ON	TN	01	02	03
All normal responses	98%	74%	61%	50%	31%	9%	13%	0%
One abnormal response	2%	16%	17%	0%	25%	35%	26%	11%
Two abnormal responses	0%	10%	22%	50%	44%	56%	61%	89%

Table 64. Classification of VWF stages by temperature and pain sensory tests on the basis of a VWF symptom classification rule.

Classes of VWF Symptoms Using Rule*				
Actual VWF Stage	No Symptoms	One or More Symptoms	Total Actually in Stage	Percent Correctly Classified
00(control) 00(exposed)	91	12 (false positives)	103	88%
0T, 0N, TN 01, 02 and 03	38 (false negatives)	106	144	74%
Total in VWF symptom classes	129	118	247	
Percent of VWF symptom classes in actual VWF stage	71%	90%		80%

*VWF Symptom Classification Rule

Temperature test result	Pain test result
N	N = no symptoms
N	A
A	N = one or more symptoms
A	A

Note: Twenty-one workers were excluded because of abnormal skin temperatures.

Table 65. Classification of VWF stages by temperature and pain sensory tests on the basis of a blanching classification rule.

Actual VWF Stage	Classes of Blanching Using Rule*		Total Actually in Stage	Percent Correctly Classified
	No Blanching Symptoms	Blanching Symptoms		
00(control) 00(exposed) OT, ON, and TN	122	53 (false positives)	175	70%
01, 02, and 03	7 (false negatives)	65	72	90%
Total in blanching classes	129	118	247	
Percent of blanching classes in actual VWF stage	95%	55%		76%

*Blanching Classification Rule

Temperature test result	Pain test result	
N	N	= no blanching symptoms
N	A	
A	N	= blanching symptoms
A	A	

Note: Twenty-one workers were excluded because of abnormal skin temperatures.

APPENDIX A

SUBJECT CONSENT FORM

Form Approved
O.M.B. 068- S77056
Exp. October 1978

U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE

Public Health Service

Center for Disease Control

National Institute for Occupational Safety and Health

Cincinnati, Ohio 45226

Project Title: Prevalence of Raynaud's Disease in Chipper and Grinder Operators Using Vibrating Hand Tools

CDC / NIOSH (C) TF 2.21
9-77

U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE

Public Health Service

Center for Disease Control

National Institute for Occupational Safety and Health

Cincinnati, Ohio 45226

Part I. Project Description

Project Title and Number: Prevalence of Raynaud's Disease in Chippers and Grinder Operator's Using Vibrating Hand Tools (G-21, 7-9277328)

Project Director: Mr. Donald Wasserman
National Institute for Occupational Safety and Health
4676 Columbia Parkway
Cincinnati, Ohio 45226
Telephone: (513) 684-8485

Purpose and Benefits: The major purposes of this study is to determine the prevalence of (VWF) Vibration White Finger syndrome (Raynaud's Disease) and relate this to vibratory hand-tool use and vibration dose testing a work population of chippers and grinders known to be exposed to vibrating tools. Further, the results from this study will be used to (1) establish a dose-response relationship regarding vibration effects for the studied populations; (2) provide preliminary technical guidelines to tool manufacturers for the reduction of vibration in the tool types studied, and (3) investigate the validity of certain medical tests for early detection of VWF syndrome.

II. CONSENT TO PARTICIPATE

I,_____, age_____, hereby voluntarily agree to cooperate in the above named study and to undergo the tests listed in Attachment A. The study has been discussed with me and I have been given a copy of this document. I understand that:

1. The procedures and tests to be followed are as stated in Attachment A with those procedures which are experimental so identified.

2. Attendant discomforts and risks are as noted in Attachment A and, except as noted, are minimal and provision has been made for any necessary emergency medical care, and I have been told what to do if I have any reaction.

3. Benefits are as indicated in the Purpose and Benefits Section in Part I.

4. If alternative procedures advantageous to me are available, they are specified in Attachment A; and if they become available during the project, the procedure most advantageous for me will be indicated and used or an explanation will be given to me as to use of any other procedure.

5. My inquiries will be answered by the project director or other personnel involved in the project or by Mr. Donald Wasserman, whose phone number is 513-684-8485.

6. I am free to terminate my consent and to discontinue participation in the project at any time without prejudice to myself.

7. My identity and my relationship to any information (1) disclosed by me in completing any project questionnaire and (2) reported by me or derived from me during my participation in the above named project shall be kept confidential and will not be disclosed to others without my written consent except as required by law and except that such information will be used for statistical and research purposes in such a manner that no individual can be identified. I understand that if any information is found out concerning me that can endanger the health and safety of others, this information will be given to the proper authority.

8. If any of my medical records are required for purposes of this project, a separate written consent for release of the records will be requested from me.

9. There will be questions that I will be asked to answer, and my inquiries concerning the questions will be answered by Mr. Donald Wasserman, whose phone number is 513-684-8485.

10. A report of any significant information from the study that specifically concerns me, including medical information, will be furnished by the Project Officer or his designated representative to me or to my designated physician(s) upon completion of the study or earlier if appropriate.

11. SIGNATURE _____ DATE _____
Subject

SIGNATURE _____ DATE _____
Parent or Guardian

INVESTIGATOR _____
Name, Title and Signature

III. REQUEST AND AUTHORIZATION FOR RELEASE OF INFORMATION

A. I _____, hereby request and authorize the Project Director to inform the following physicians whose names and addresses I have entered below of any significant findings from the above named study concerning me. (Do not leave blank. Write "No" where you do not wish to give a name and address).

1. My Personal physician(s):

Dr. _____

Street: _____

City: _____

2. (Company), (Other) physician:

Dr. _____

Street: _____

City: _____

Signature _____ Date _____

B. I _____, hereby do/do not request and authorize the Project Director to allow the presence as a medical observer of (plant physician) Dr. _____ as I am undergoing the study procedures, tests, and medical examination listed in Attachment A.

Signature _____ Date _____

IV. Since a project questionnaire is required, it will constitute this Part IV as a separate attachment to be retained by the Project Director. A copy of the questionnaire is not retained by the participant.

ATTACHMENT A

A. Project Title and Number: Prevalence of Raynaud's Disease in Chippers and Grinder Operator's Using Vibrating Hand Tools (G-21, 7-9277328).

B. Procedures and tests which involve human subjects in conduct of subject project are as follows:

A study questionnaire consisting of a non-medical and medical portions will be completed. The non-medical portion consisting of: (1) demographic data, (2) work history data, (3) information on the types and usage of vibrating tools. The medical portion consisting of: (1) occupational history and (2) specific medical history designed to detect Raynaud's Phenomenon and its complications.

A specific medical examination of the arms and legs designed to detect Raynaud's Phenomenon.

A noninvasive series of medical tests (i.e. tests which do not pierce the skin): x-rays of the hands; tests which determine touch sensitivity of the fingers (aesthesiometry, two point discrimination, touch, mild heat and pin prick); measurement of finger diameters; measurement of finger blood flow (plethysmography).

A series of engineering tests (mechanical impedance and acceleration) designed to determine the amount and characteristics of the vibration getting to the hands.

C. Rights under the Privacy Act of 1974 Title 5 United States Code, Section 552(a)(e)(3)

The information required to be given to me under the Privacy Act of 1974 is as follows:

1) Authority for collecting information is the Occupational Safety and Health Act of 1970

2) The principal purposes are as stated in Section I, Item 3.

3) Routine use of this information is in developing criteria and programs for a safe and healthful place of employment as published on October 1, 1975 CDC-NIOSH-0121.00, Federal Register.

4) I do not have to furnish any information I do not wish to. Nothing happens to me as a result of my not providing information, whether all or in part of that requested, except that I may be terminated from the project.

APPENDIX B

STUDY QUESTIONNAIRE

U.S. DEPARTMENT OF HEALTH, EDUCATION AND WELFARE

Public Health Service

Centers for Disease Control

National Institute for Occupational Safety and Health

STUDY QUESTIONNAIRE

Prevalence of Raynaud's Disease in Chipper and Grinder Operators Using Vibrating Hand Tools

CDC/NIOSH (C)TF 2.21A
9-77

INTERVIEWER:_____ Checked BY_____

DATE OF INTERVIEW:_____
MO DAY YR

SUBJECT IDENTIFICATION

CASE NO.:_____

LAST NAME:_____

FIRST NAME:_____

MIDDLE INITIAL:_____

ADDRESS:_____

CITY:_____

STATE_____ ZIP CODE_____

PERSONAL DATA

1. TELEPHONE (_____)_____
AREA CODE

2. RACE/ETHNIC CODE
1. White, not of Hispanic Origin
2. Black, not of Hispanic Origin
3. Hispanic
4. American Indian or Alaskan Native
5. Asian or Pacific Islander
6. Other

_____

3. SEX 1. Male 2. Female _____

4. What is your date of birth? (month/day/year)_____/_____/_____

5. Are you right-handed OR left-handed? _____

OCCUPATIONAL HISTORY

READ: Now I'm going to ask you about all the jobs you've held, including part-time jobs and military service. I'd like to begin with your present job, here at (Insert-Employer), and go back to your first job.

JOBS WITH PRESENT EMPLOYER

1. What department do/did you work in?
2. What is/was your occupation or job title?
3. In what month and year, did you start working on this/that job?
4. And, in what year and month did you stop working on this/that job?
5. Are/were you a full-time OR part-time employee?
6. What shift do/did you regularly work? (Do you work 7 to 3, 3 to 11, OR 11 to 7?)
7. On this/that job, do/did you use any vibratory hand tools?

IF YES ASK:

8. What kind of vibratory hand tool?
9. Did you use any other vibratory hand tools?

10. Do/did you do most of your work sitting OR standing?
11. Do/did you almost always wear gloves while working with a vibratory hand tools?
12. Have you had any other jobs here at _____ where you used vibratory hand tools?

(IF YES: REPEAT Q. 1-11. ASK Q. 12 UNTIL YOU HAVE RECORDED ALL JOBS WHERE VIBRATORY HAND TOOLS WERE USED.)

	DEPARTMENT	JOB TITLE	DATES START/END	FULL-TIME PART-TIME	SHIFT	TOOL TYPE	POSITION	GLOVES
1.				1 FT 2 PT	1 7-3 2 3-11 3 11-7 4 ROTATE		1 SITTING 2 STANDING	1 YES 2 NO
2.				1 FT 2 PT	1 7-3 2 3-11 3 11-7 4 ROTATE		1 SITTING 2 STANDING	1 YES 2 NO
3.				1 FT 2 PT	1 7-3 2 3-11 3 11-7 4 ROTATE		1 SITTING 2 STANDING	1 YES 2 NO
4.				1 FT 2 PT	1 7-3 2 3-11 3 11-7 4 ROTATE		1 SITTING 2 STANDING	1 YES 2 NO

PREVIOUS EMPLOYMENT

(REPEAT Q. 2-9 FOR EACH JOB. REPEAT Q. 1 UNTIL YOU ASCERTAIN THAT YOU HAVE RECORDED ALL RELEVANT JOBS, INCLUDING PART TIME EMPLOYMENT AND MILITARY SERVICE. * ON Q. 9, IF NO HAND TOOLS WERE USED ON A JOB WRITE "NONE" UNDER "HAND TOOLS".)

1. Now, where did you work before you started working for _____?
2. What kind of a company is it; what do they do there?
3. In what month and year did you start working there?
4. And, in what month and year did you stop working there?
5. Did you work full-time or part-time?
6. What was your occupation or job title?
7. On this job did you work with vinyl chloride?
8. Did you use any vibrating hand tools?

IF YES ASK: 9. What kind of vibratory hand tool?

10. Did you use any other vibratory hand tools?

EMPLOYER	TYPE OF COMPANY	DATE STARTED/ENDED	FULL TIME PART TIME	JOB TITLE	VINYL CHLORIDE	HAND TOOLS
1.					1 YES 2 NO 8 DK	
2.					1 YES 2 NO 8 DK	
3.					1 YES 2 NO 8 DK	
4.					1 YES 2 NO 8 DK	
5.					1 YES 2 NO 8 DK	
6.					1 YES 2 NO 8 DK	
7.					1 YES 2 NO 8 DK	
8.					1 YES 2 NO 8 DK	

HOBBIES

1. Have you ever had any hobbies in which you use vibratory hand tools?
   1. YES NO 8 DK

IF YES ASK:

2. What kind of hobby?

3. What kinds of vibratory hand tools do/did you use?

4. In what year did you first start doing this?

5. In what year did you stop doing this?

6. Have you had any other hobbies using vibratory hand tools?

HOBBY	TOOL	START YEAR	END YEAR
		19__	19__ 7__CURRENT
		19__	19__ 7__CURRENT
		19__	19__ 7__CURRENT

II SYMPTOMS

(ASK EACH Q. MARKED WITH * . FOR EACH YES ANSWER, ASK THE SECONDARY QUESTIONS BELOW. FOR LOCATION, CHECK WHETHER OR NOT A SPECIFIC HAND LOCATION WAS REPORTED, AND MARK THE LOCATION ON THE DIAGRAM. USE THE NUMBER OF THE QUESTIONS: E.G., A .5 ON A FINGER TIP FOR A SUBJECT WITH NUMBNESS ON THAT PART OF THE FINGER. THERE MAY BE MORE THAN ONE NUMBER ON ONE AREA OF THE DIAGRAM.)

SECONDARY QUESTIONS

IF YES ASK:

LOCATION Where do you usually have this?
(On what finger or fingers? Where on your finger?)

OCCURENCE Do you usually have this in warm weatner OR in cool or cold weather?

ONSET In what year did you first notice this?

	SYMPTOMS	RESPONSE	LOCATION	OCCURENCE	ONSET
*1.	Do your fingers, or parts of your fingers ever turn white?	1___YES 2___NO 8___DK	1__REPORTED 8___DK	1____WARM 2__COOL/COLD 8__DK	19____ 8__DK

IF YES ASK:

2. Do your fingers usually turn white in tne:

Morning?.....1_____
Afternoon?.....2_____
OR
At night?.....3_____
NO USUAL TIME.....4_____

*3. Do you ever have tingling in your fingers?

RESPONSE	LOCATION	OCCURENCE	ONSET
1___YES	1__REPORTED	1____WARM	19____
2___NO	8___DK	2__COOL/COLD	8__DK
8___DK		8__DK	

*4. What about numbness in your fingers?

RESPONSE	LOCATION	OCCURENCE	ONSET
1___YES	1__REPORTED	1____WARM	19____
2___NO	8___DK	2__COOL/COLD	8__DK
8___DK		8__DK	

5. Have you had trouble sleeping because of numbness or tingling in your hands or fingers?.....1.___YES 2.___ 8___DK

IF YES ASK:

6. On the average, how long does the tingling/numbness last?

(IF THE RESPONDENT CANNOT GIVE AN ESTIMATED TIME, READ THE CODING CATEGORIES.)

1_____LESS THAN 5 MIN.
2_____LESS THAN 15 MIN.
3_____LESS THAN 30 MIN.
4_____LESS THAN 1 HOUR
5_____MORE THAN 1 HOUR
8_____DK

7. What do you usually do to get rid of the tingling/numbness?

VERBATIM RESPONSE_____

*8. Do you ever have aching in your fingers?

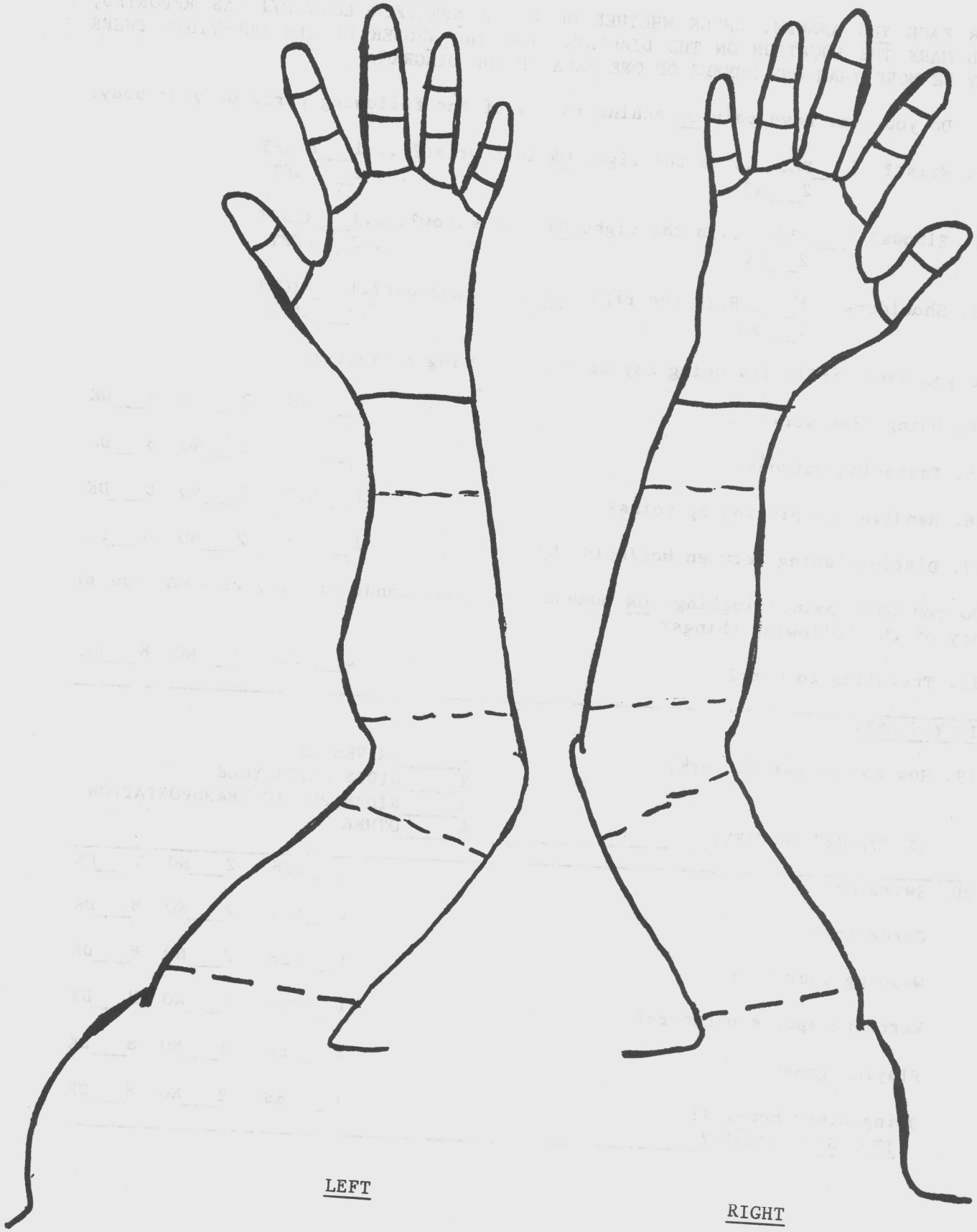
RESPONSE	LOCATION	OCCURENCE	ONSET
1___YES	1__REPORTED	1____WARM	19____
2___NO	8___DK	2__COOL/COLD	8__DK
8___DK		8__DK	

*9. What about pain in your hands?

RESPONSE	LOCATION	OCCURENCE	ONSET
1___YES	1__REPORTED	1____WARM	19____
2___NO	8___DK	2__COOL/COLD	8__DK
8___DK		8__DK	

*10. Did you ever have frost-bite or painful, swollen, redish-blue fingers?

RESPONSE	LOCATION	OCCURENCE	ONSET
1___YES	1__REPORTED	1____WARM	19____
2___NO	8___DK	2__COOL/COLD	8__DK
8___DK		8__DK	



LEFT

RIGHT

FOR EACH YES ANSWER, CHECK WHETHER OR NOT A SPECIFIC LOCATION WAS REPORTED, AND MARK THE LOCATION ON THE DIAGRAM. USE THE NUMBER OF THE QUESTION: THERE MAY BE MORE THAN ONE NUMBER ON ONE AREA OF THE DIAGRAM.

Do you ever have pain OR aching in any of the following parts of your body:

11. Wrist? 1___YES.....In the right OR left wrist?....1___RIGHT
2___NO ....2___LEFT

12. Elbows? 1___YES.....In the right OR left elbow?....1___RIGHT
2___NO ....2___LEFT

13. Shoulders 1___YES.In the right OR left shoulder?.1___RIGHT
2___NO .2___LEFT

Do you have difficulty doing any of the following activities?

14. Doing fine work? 1___YES 2___NO 8___DK

15. Fastening buttons? 1___YES 2___NO 8___DK

16. Handling or picking up coins? 1___YES 2___NO 8___DK

17. Distinguishing between hot/cold objects? 1___YES 2___NO 8___DK

Do you have pain, tingling, OR numbness in your hands or fingers when you do any of the following things?

18. Traveling to work? 1___YES 2___NO 8___DK

IF YES ASK:

19. How do you get to work?
1____DRIVES CAR
2____RIDES MOTORCYCLE
3____RIDES PUBLIC TRANSPORTATION
IF "OTHER" SPECIFY:_____ 4____OTHER

---

20. Swimming? 1___YES 2___NO 8___DK

Gardening? 1___YES 2___NO 8___DK

Washing your car? 1___YES 2___NO 8___DK

Watching sports outdoors? 1___YES 2___NO 8___DK

Playing games 1___YES 2___NO 8___DK

Doing other hobbies? 1___YES 2___NO 8___DK
IF YES: SPECIFY_____

HEALTH HISTORY

I'm now going to read a list of health conditions. Have you ever been told by a doctor that you had any of the following conditions? Please answer YES or NO to each one.
(READ EACH CONDITION AND RECORD A RESPONSE. IF YES, ASK THE SECONDARY QUESTION BELOW.)

SECONDARY QUESTIONS

IF YES ASK:

DATE — In what year were you first told about this condition?

(For Q. 10: — In what year did you first notice this?)

	CONDITION	RESPONSE	DATE		CONDITION	RESPONSE	DATE
1.	Rheumatic fever?	1 YES 2 NO 8 DK	19__ 8__ DK	6.	Psoriasis?	1 YES 2 NO 8 DK	19__ 8__ DK
2.	Any type of heart trouble?	1 YES 2 NO 8 DK	19__ 8__ DK	7.	Raynaud's Disease or "white finger"?	1 YES 2 NO 8 DK	19__ 8__ DK
3.	High blood pressure?	1 YES 2 NO 8 DK	19__ 8__ DK	8.	Any kind of circulatory problem in your hands or feet?	1 YES 2 NO 8 DK	19__ 8__ DK
4.	Neuritis?	1 YES 2 NO 8 DK	19__ 8__ DK	9.	Arthritis?	1 YES 2 NO 8 DK	19__ 8__ DK
5.	Diabetes?	1 YES 2 NO 8 DK	19__ 8__ DK	10.	Do you frequently have aching or pain in your joints?	1 YES 2 NO 8 DK	19__ 8__ DK

MEDICINES

1. During the last six months, were you regularly taking any kind of tablets, pills, or other medicines?

1___YES 2___NO 8___DK

IF YES ASK:

2. What were you taking?

3. Were you taking any other medicines?

4. What about non-prescription medicines; things anyone can buy at the store or grocery?

VERBATIM RESPONSE_____

5. Are you now taking any kind of medicine on a regular basis?

1___YES 2___NO 8___DK

IF YES ASK:

2. What are you taking?

3. Are you taking any other medicines?

4. What about non-prescription medicines; things anyone can buy at the store or grocery?

VERBATIM RESPONSE_____

9. Are you allergic to any kind of drug or medicine?

1___YES 2___NO 8___DK

IF YES ASK:

10. What kind of drug/medicine?
SPECIFY_____

11. Are you allergic to any kind of food?

1___YES 2___NO 8___DK

IF YES ASK:

10. What kind of food?
SPECIFY_____

FAMILY HISTORY

1. Have any of your blood relatives (parents, brothers, sisters) been told by a doctor that they have white fingers or Raynaud's disease?

1___YES 2___NO 8___DK

IF YES ASK:

2. Which relatives have this?_____
3. Do any of your other blood relatives have "white fingers"?

1___YES 2___NO 8___DK

IF YES ASK:

4. Which relative?_____(RELATIVE CODE #)

RELATIVE CODE

1___Mother	4___Sisters
2___Father	5___Cousins-M
3___Brothers	6___Cousins-F
SPECIFY "OTHER" RELATIVE_____	7___Other

5. Has he/she (have they) ever used vibratory hand tools at work, or in a hobby?

(ENTER RELATIVE CODE. E.G., 1 FOR MOTHER) 1___YES 2___NO 8___DK___RELATIVE
1___YES 2___NO 8___DK___RELATIVE
1___YES 2___NO 8___DK___RELATIVE

Have any of your blood relatives ever been told by a doctor that they have any of the following health conditions?

6. High blood pressure? 1___YES 2___NO 8___DK

7. Diabetes? 1___YES 2___NO 8___DK

8. Cardiovascular diseases 1___YES 2___NO 8___DK

9. Arthritis? 1___YES 2___NO 8___DK

10. Do any of them have frequent pain or aching in their joints? 1___YES 2___NO 8___DK

In this part of the interview, I'll be asking you about your social habits.

SMOKING HISTORY

1. Do you now smoke cigarettes? 1____YES 2____NO

IF NO:

2. Have you ever smoked cigarettes? 1____YES 2____NO

IF NO TO Q. 1 AND Q. 2: GO TO PIPE SMOKING

ASK EX-SMOKERS:

3. How old were you when you gave up smoking cigarettes? _____AGE 8____DK

4. How old were you when you started smoking cigarettes regularly _____AGE 8____DK
6_____NEVER REGULARLY

5. On the average, how many cigarettes do/did you smoke a day? _____CIG/DAY 8____DK

6. DO/did you inhale the cigarette smoke? 1____YES 2____NO 8____DK

PIPE SMOKING

7. Do you now smoke a pipe? 1____YES 2____NO

IF NO:

8. Have you ever smoked a pipe? 1____YES 2____NO

IF NO TO Q. 7 AND Q. 8 GO TO CIGAR SMOKING

ASK EX-PIPE SMOKERS:

9. How old were you when you gave up smoking a pipe? _____AGE 8____DK

10. How old were you when you started smoking a pipe regularly? _____AGE 8____DK
6_____NEVER REGULARLY

11. How many bowlsful of tobacco do/did you smoke per week? _____BOWLFULS/WK 8____DK

12. Do/did you inhale the pipe smoke? 1____YES 2____NO 8____DK

CIGAR SMOKING

13. Do you now smoke cigars? 1____YES 2____NO 8____DK

IF NO:

14. Have you ever smoked cigars? 1____YES 2____NO 8____DK

IF NO TO Q. 13 AND Q. 14: GO TO ALCOHOL CONSUMPTION

ASK EX-CIGAR SMOKERS

15. How old were you when you stopped smoking cigars? ____AGE 8____DK

16. How old were you when you started smoking cigars regularly? ____AGE 8____DK
6____NEVER REGULARLY

17. How many cigars do/did you smoke a week? ____CIGARS/wk 8____DK

18. Do/did you inhale the cigar smoke? 1____YES 2____NO 8____DK

ALCOHOL CONSUMPTION

1. Have you drunk as many as 20 alcoholic beverages in your entire life? 1____YES 2____NO

IF NO: INTERVIEW IS FINISHED

2. Do you now drink alcoholic beverages? 1____YES 2____NO

IF NO:

3. How old were you when you gave up drinking? ____AGE 8____DK

4. How old were you when you first started drinking? ____AGE 8____DK

5. On the average, how many beers do you drink per day? ___BEER/DAY ____BEER/WK

(IF DOES NOT DRINK A BEER PER DAY ASK: "HOW MANY PER WEEK") 7___LESS 1/WK 8____DK

6. About how many bottles of wine do you drink per week? ___WINE/WK ____WINE/MO
7___LESS 1/MO 8____DK

7. About how many cocktails or drinks of other liquor do you have per week? ___DRINKS/WK ___DRINKS/MO
7___LESS 1/MO 8____DK

APPENDIX C

MEDICAL INFORMATION FORMS

Form Approved
O.M.B. 068 - S77056,
Exp. October 1978

U. S. DEPARTMENT OF HEALTH, EDUCATION AND WELFARE

Public Health Service

Center for Disease Control

National Institute for Occupational Safety and Health

MEDICAL INFORMATION

Prevalence of Raynaud's Disease in Chipper and Grinder Operators Using Vibrating Hand Tools

MEDICAL EXAMINATION

Card 2, Col.

Subject ID [ ][ ][ ][ ] 1 - 5

Blood Pressure (mm Hg)

Right Arm Systolic/Diastolic [ ][ ][ ]/[ ][ ][ ] 6 - 11

Left Arm Systolic/Diastolic [ ][ ][ ]/[ ][ ][ ] 12 - 17

Eyes: Fundoscopic Examination (check)

	Right		Left		
Arteries:	Normal [ ]	Abnormal [ ]	Normal [ ]	Abnormal [ ]	18 - 19
Veins:	Normal [ ]	Abnormal [ ]	Normal [ ]	Abnormal [ ]	20 - 21
A/V crossing:	Normal [ ]	Abnormal [ ]	Normal [ ]	Abnormal [ ]	22 - 23
Exudate:	Absent [ ]	Present [ ]	Absent [ ]	Present [ ]	24 - 25

Other Fundoscopic Findings (describe)_____ _____

_____

Mouth:

Cheilosis Absent [ ] Present [ ] 26

Tongue: Normal [ ] Redness [ ] Atrophy [ ] 27

Other: (describe)_____

_____

Heart:

Positive Findings: YES [ ] NO [ ] 28

If yes, specify:_____

_____

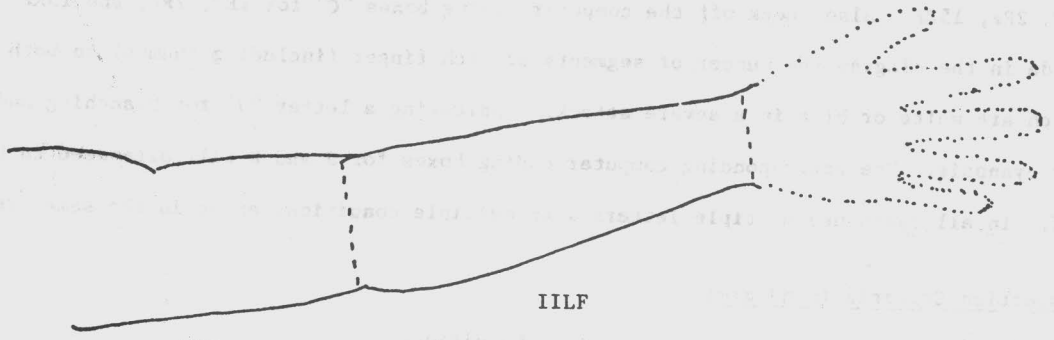
First 3 Characters of Last Name [ ][ ][ ] 75 - 77

Instructions for examining physician concerning extremity diagrams on following pages:

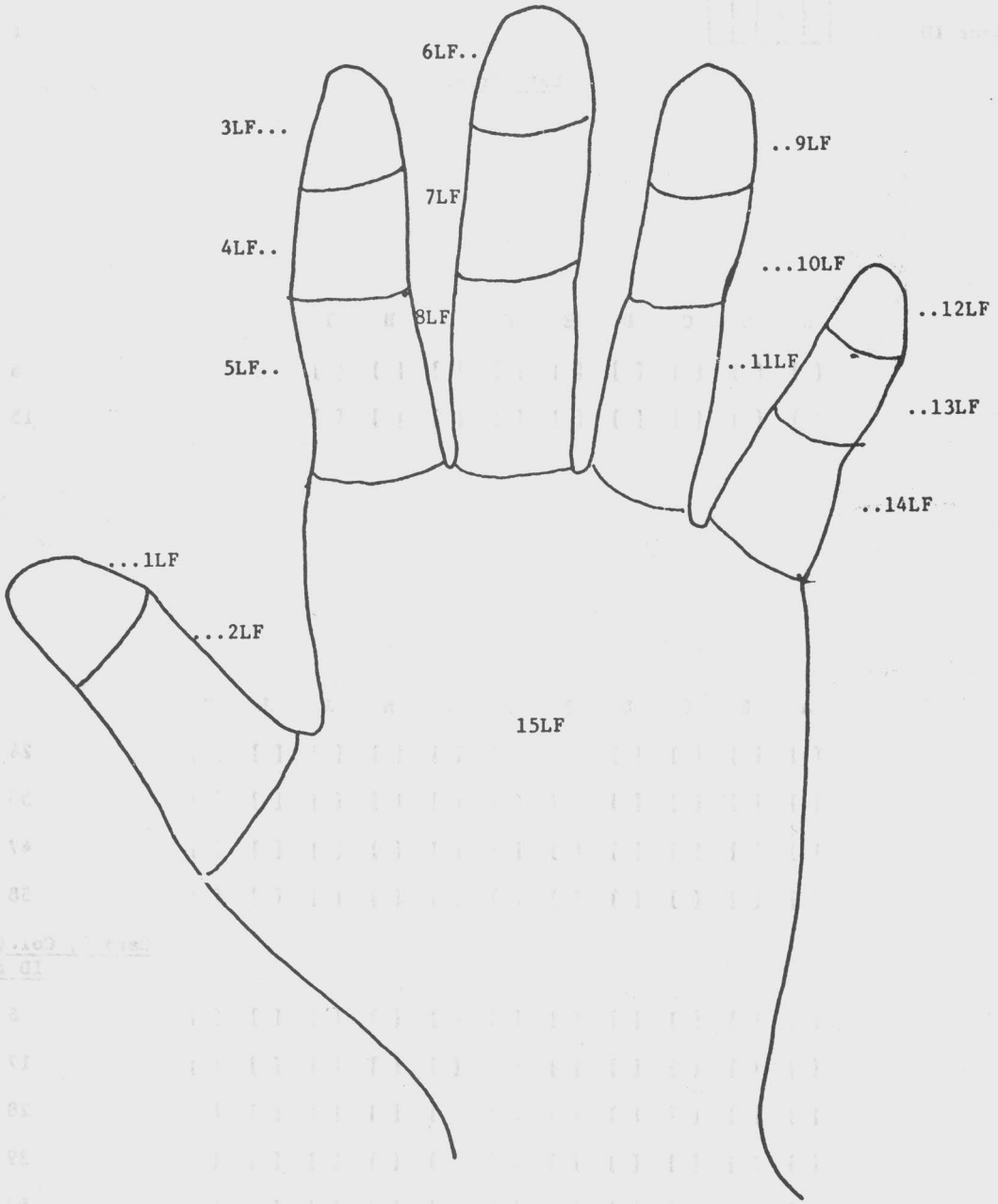
Perform inspections of both hands and arms, front and back using the coded criteria listed below. Place in each diagram the letter or letters corresponding to the items listed below in their exact location. (Example: If the right thumb had a scar on the front side, then in the area designated 1RF on the right front diagram, the position of the scar would be drawn in with a code letter "C" placed near it; if the scar extended down this same thumb to the palm, then draw in the length and ground shape of the scar indicating a "C" in areas 1RF, 2RF, 15RF. Also check off the computer coding boxes "C" for 1RF, 2RF, and 15RF. Please shade in the diagram the number of segments at each finger (including thumbs) on both hands which are white or blue in a severe attack. Indicating a letter "J' for blanching and "K" for cyanosis. The corresponding computer coding boxes for J and K will also need to be checked off. In all cases use multiple letters when multiple conditions exist in the same areas.

Inspection Criteria (hand-arm)

Code Letter	Conditions
A	Amputations
B	Deformities
C	Scars
D	Needle Marks
E	Skin Lesions
F	Knuckle Pads
G	Swelling of Joints
H	Finger Tip Ulcers
I	Subungual Hemorrhages
J	(Color) Blanching
K	(Color) Cyanosis



LEFT FRONT


6LF..
3LF...
..9LF
7LF
4LF..
...10LF
..12LF
8LF
5LF..
..11LF
..13LF
..14LF
...1LF
...2LF
15LF

LEFT FRONT

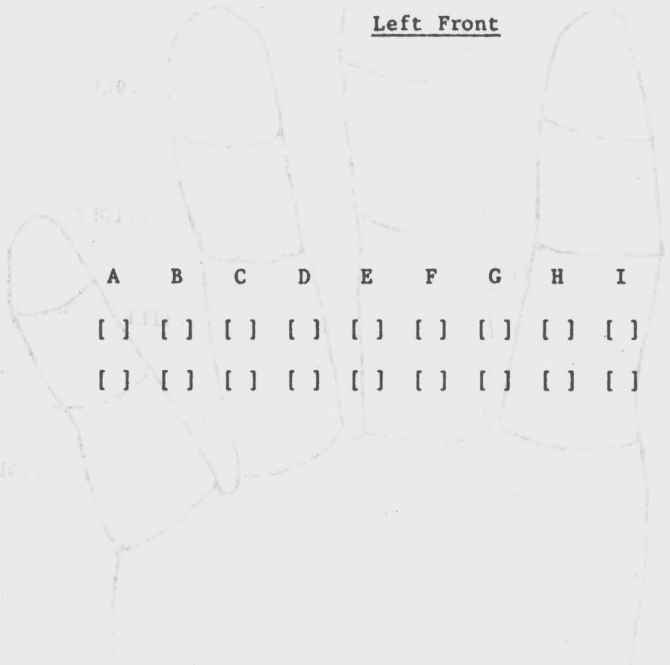
INSPECTION OF UPPER EXTREMITIES

Subject ID [ ][ ][ ][ ][ ]

Card 3, Col.

1 - 5

Left Front



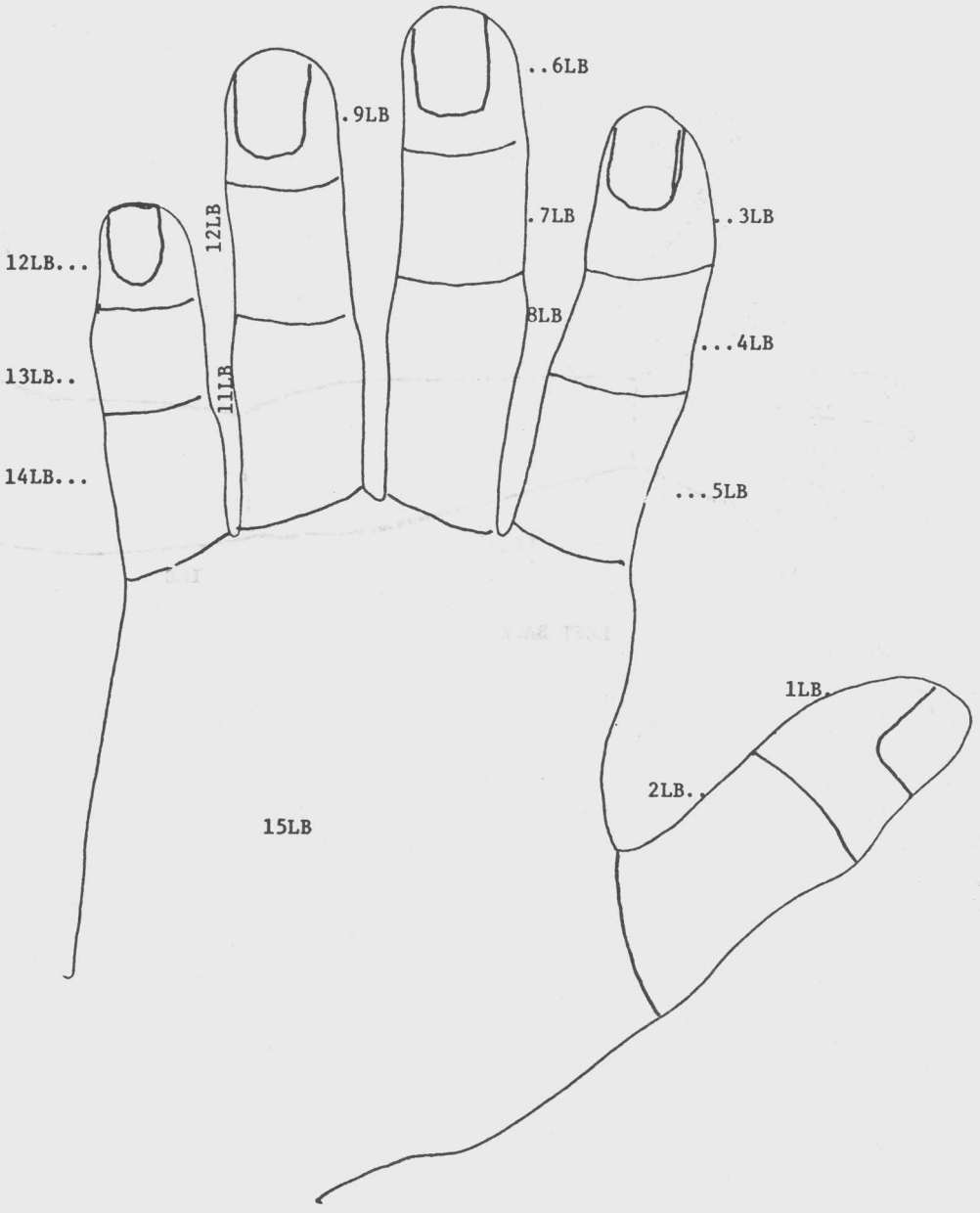
	A	B	C	D	E	F	G	H	I	
ILF	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	6 - 14
IILF	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	15 - 23

	A	B	C	D	E	F	G	H	I	J	K	
1LF	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	24 - 35
2LF	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	36 - 46
3LF	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	47 - 57
4LF	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	58 - 68
												Card 4, Col. (Subj. ID 1 - 5)
5LF	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	6 - 16
6LF	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	17 - 27
7LF	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	28 - 38
8LF	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	39 - 49
9LF	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	50 - 60
10LF	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	61 - 71
												Card 5, Col. (Subj. ID 1 - 5)
11LF	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	6 - 16
12LF	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	17 - 27
13LF	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	28 - 38
14LF	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	39 - 49
15LF	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	50 - 60

Cards 3,4,5, Cols.

First 3 Characters of Last Name [ ][ ][ ] 75 - 77

LEFT BACK


..6LB
.9LB
12LB
.7LB
..3LB
12LB...
8LB
...4LB
13LB..
11LB
14LB...
...5LB
1LB.
2LB..
15LB

LEFT BACK

INSPECTION OF UPPER EXTREMITIES

Subject ID [ ][ ][ ][ ]

Card 5, Col.

1 - 5

Left Back

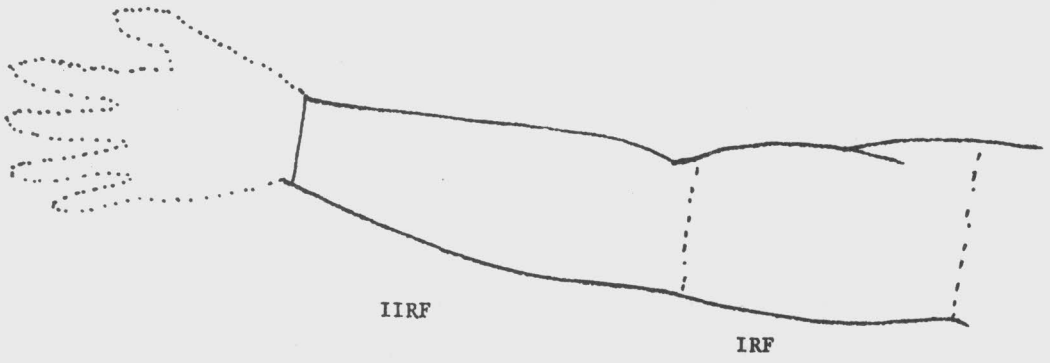
	A	B	C	D	E	F	G	H	I	
ILB	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	6 - 14
IILB	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	15 - 23

	A	B	C	D	E	F	G	H	I	J	K	
1LB	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	24 - 35
2LB	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	36 - 46
3LB	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	47 - 57
4LB	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	58 - 68
												Card 7, Col. (Subj. ID 1 - 5)
5LB	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	6 - 16
6LB	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	17 - 27
7LB	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	28 - 38
8LB	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	39 - 49
9LB	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	50 - 60
10LB	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	61 - 71
												Card 8, Col. (Subj. ID 1 - 5)
11LB	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	6 - 16
12LB	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	17 - 27
13LB	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	28 - 38
14LB	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	39 - 49
15LB	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	50 - 60

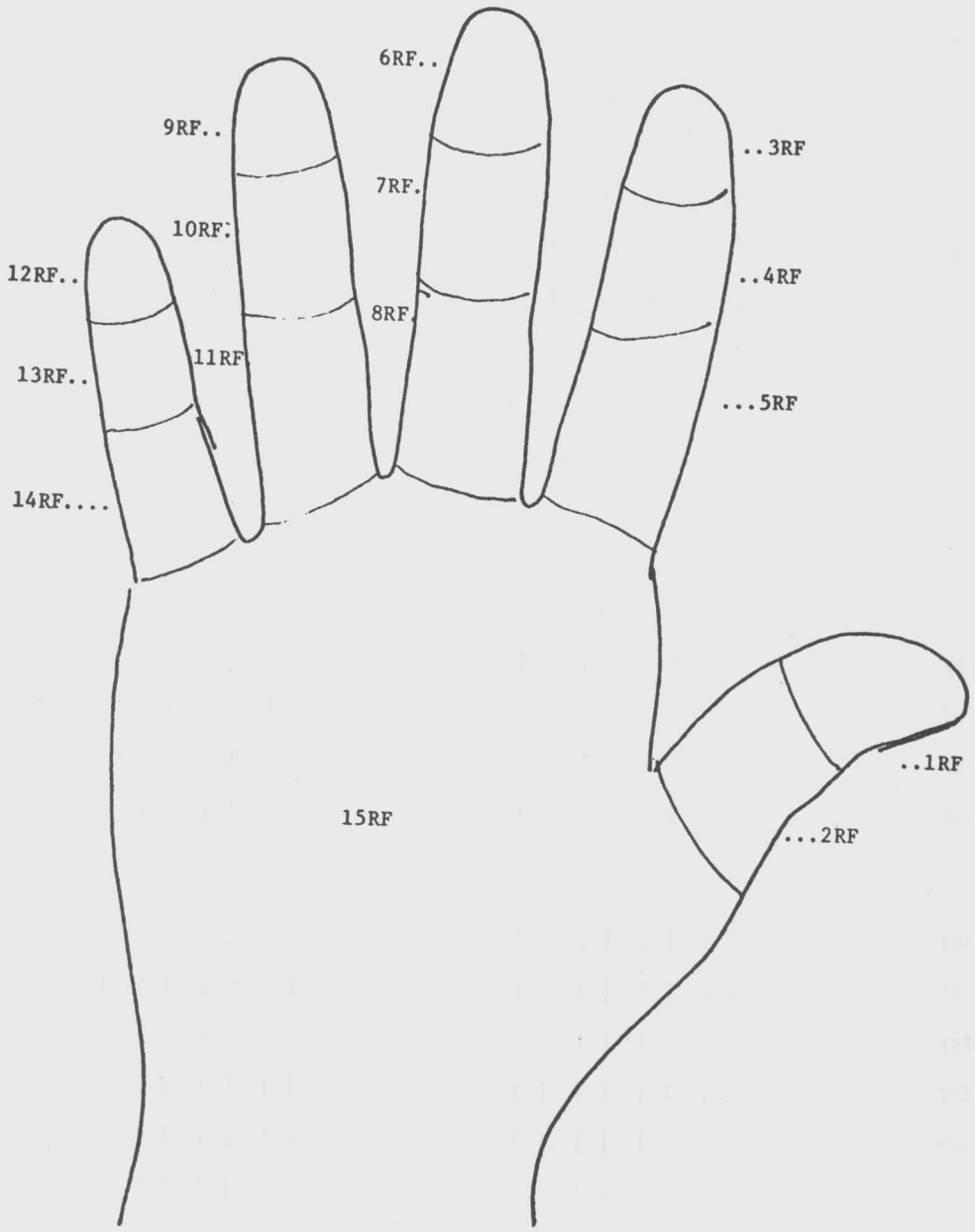
Cards 6,7,8, Cols.

First 3 Characters of Last Name [ ][ ][ ]

75 - 77



RIGHT FRONT


6RF..
9RF..
..3RF
7RF.
10RF.
12RF..
..4RF
8RF.
11RF
13RF..
...5RF
14RF....
..1RF
15RF
...2RF

RIGHT FRONT

INSPECTION OF UPPER EXTREMITIES

Subject [ ][ ][ ][ ][ ]

Card 9, Col.

1 - 5

Right Front

	A	B	C	D	E	F	G	H	I	
IRF	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	6 - 14
IIRF	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	15 - 23

	A	B	C	D	E	F	G	H	I	J	K	
1RF	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	24 - 35
2RF	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	36 - 46
3RF	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	47 - 57
4RF	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	58 - 68
												Card 10, Col. (Subj. ID 1-5)
5RF	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	6 - 16
6RF	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	17 - 27
7RF	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	28 - 38
8RF	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	39 - 49
9RF	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	50 - 60
10RF	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	61 - 71
												Card 11, Col. (Subj. ID 1-5)
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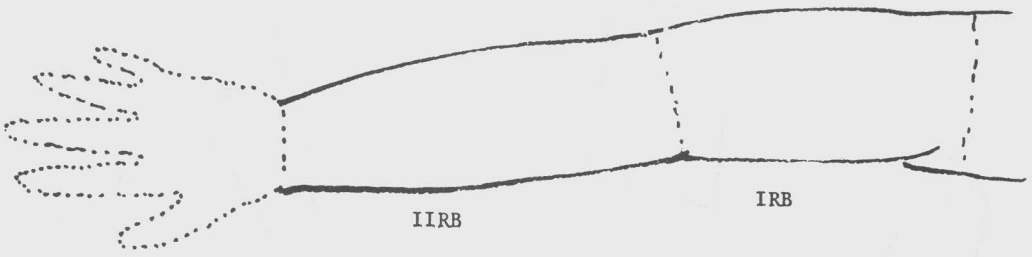
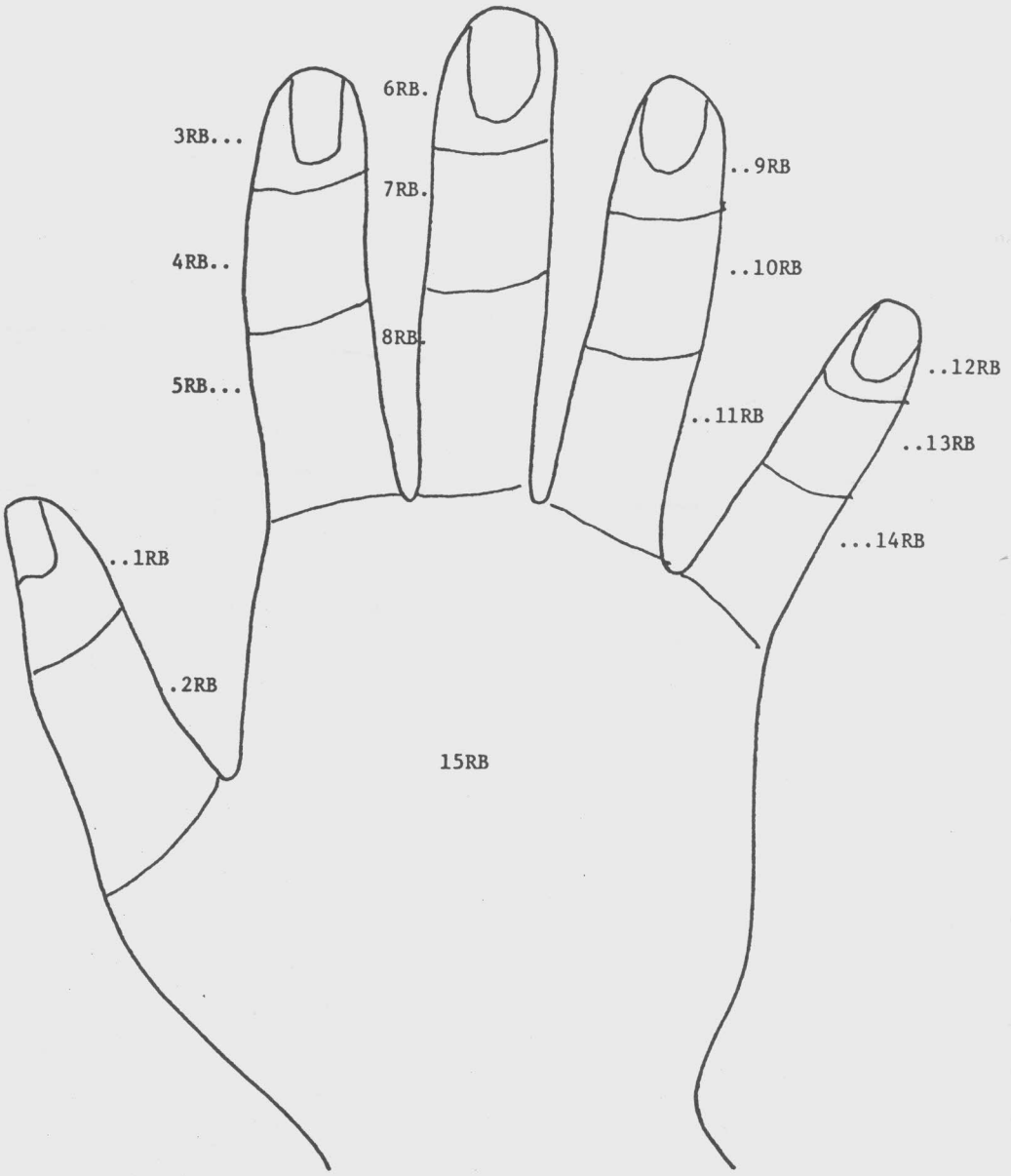
12RF	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	17 - 27
13RF	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	28 - 38
14RF	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	39 - 49
15RF	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	50 - 60

Cards 3,4,5, Cols.

First 3 Characters of Last Name [ ][ ][ ] 75 - 77



RIGHT BACK


3RB...
6RB.
..9RB
4RB..
7RB.
..10RB
8RB.
5RB...
..12RB
..11RB
..13RB
...14RB
..1RB
.2RB
15RB

RIGHT BACK

INSPECTION OF UPPER EXTREMITIES

Subject ID [ ][ ][ ][ ][ ]

Card 12, Col.

1 - 5

Right Back

	A	B	C	D	E	F	G	H	I	
IRB	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	6 - 14
IIRB	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	15 - 23

	A	B	C	D	E	F	G	H	I	J	K	
1RB	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	24 - 35
2RB	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	36 - 46
3RB	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	47 - 57
4RB	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	58 - 68
												Card 13, Col. (Subj. ID 1 - 5)
5RB	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	6 - 16
6RB	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	17 - 27
7RB	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	28 - 38
8RB	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	39 - 49
9RB	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	50 - 60
10RB	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	61 - 71
												Card 14, Col. (Subj. ID 1 - 5)
11RB	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	6 - 16
12RB	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	17 - 27
13RB	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	28 - 38
14RB	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	39 - 49
15RB	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	50 - 50

Cards 12,13,14,Cols.

First 3 Characters of Last Name [ ][ ][ ]

75 - 77

EXAMINATION OF UPPER EXTREMITIES

Card 15, Col.

Subject ID [ ][ ][ ][ ] 1 - 5

Palpation

	RIGHT	LEFT	
Brachial:	beats/min. [ ][ ][ ]/[ ][ ][ ]	beats/min. [ ][ ][ ]/[ ][ ][ ]	6 - 17
Radial:	beats/min. [ ][ ][ ]/[ ][ ][ ]	beats/min. [ ][ ][ ]/[ ][ ][ ]	

Findings

Axilla:	Positive [ ] Negative [ ]	Positive [ ] Negative [ ]	18 - 19
Describe:	_____	Describe: _____	
	_____	_____	

Test Measurements

a) Skin thickness

	RIGHT	LEFT	
Biceps	[ ][ ][ ] mm	Biceps [ ][ ][ ] mm	20 - 25
Triceps	[ ][ ][ ] mm	Triceps [ ][ ][ ] mm	26 - 3
Forearm	[ ][ ][ ] mm	Forearm [ ][ ][ ] mm	32 - 37

b) Mobility range

	RIGHT	LEFT	
Wrist	None [ ] Partial [ ] Full [ ]	None [ ] Partial [ ] Full [ ]	38 - 39
Fingers	None [ ] Partial [ ] Full [ ]	None [ ] Partial [ ] Full [ ]	40 - 41
Describe:	_____	Describe: _____	
	_____	_____	

First 3 Characters of Last Name [ ][ ][ ] 75 - 77

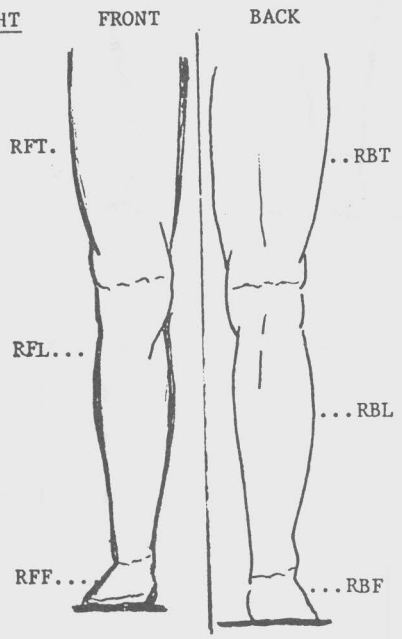
INSPECTION OF LOWER EXTREMITIES

Card 16, Col.

Subject ID [ ][ ][ ][ ] 1 - 5

Inspection Criteria

Code	Condition
A	Amputations
B	Deformities
C	Scars
J	(Color) Blanching
K	(Color) Cyanosis



	A	B	C	J	K		A	B	C	J	K	
RFT	[ ]	[ ]	[ ]	[ ]	[ ]	RBT	[ ]	[ ]	[ ]	[ ]	[ ]	6 - 15
RFL	[ ]	[ ]	[ ]	[ ]	[ ]	RBL	[ ]	[ ]	[ ]	[ ]	[ ]	16 - 25
RFF	[ ]	[ ]	[ ]	[ ]	[ ]	RFF	[ ]	[ ]	[ ]	[ ]	[ ]	26 - 35

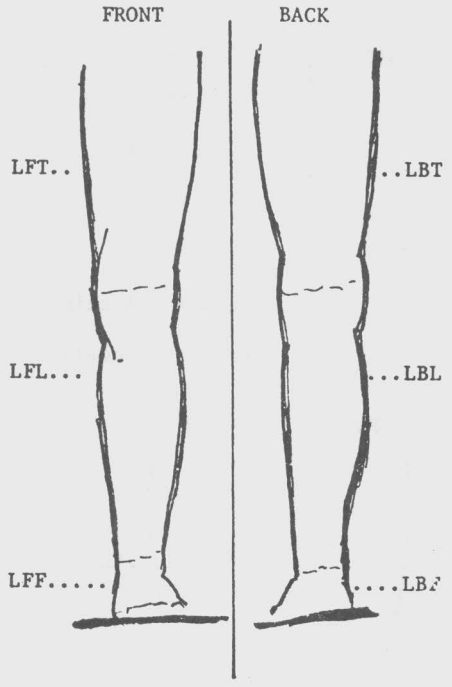
First 3 Characters of Last Name [ ][ ][ ] 75 - 77

INSPECTION OF LOWER EXTREMITIES

Subject ID [ ][ ][ ][ ][ ]

Card 17, Col.

1 - 5



	A	B	C	J	K		A	B	C	J	K	
LFT	[ ]	[ ]	[ ]	[ ]	[ ]	LBT	[ ]	[ ]	[ ]	[ ]	[ ]	6 - 15
LFL	[ ]	[ ]	[ ]	[ ]	[ ]	LBL	[ ]	[ ]	[ ]	[ ]	[ ]	16 - 25
LFF	[ ]	[ ]	[ ]	[ ]	[ ]	LBF	[ ]	[ ]	[ ]	[ ]	[ ]	26 - 35

First 3 Characters of Last Name [ ][ ][ ]

75 - 77

EXAMINATION OF LOWER EXTREMITIES

Card 18, Col.

Subject ID [ ][ ][ ][ ] 1 - 5

Palpation

	RIGHT	LEFT	
Dorsalis pedis	beats/min. [ ][ ][ ]/[ ][ ][ ]	beats/min. [ ][ ][ ]/[ ][ ][ ]	6 - 11
Tibialis ant.	beats/min. [ ][ ][ ]/[ ][ ][ ]	beats/min. [ ][ ][ ]/[ ][ ][ ]	12 - 17
Popliteal art.	beats/min. [ ][ ][ ]/[ ][ ][ ]	beats/min. [ ][ ][ ]/[ ][ ][ ]	18 - 23

Test Measurements

a) Skin thickness

	RIGHT	LEFT	
Calf	[ ][ ][ ] mm	Calf [ ][ ][ ] mm	24 - 29
Thigh	[ ][ ][ ] mm	Thigh [ ][ ][ ] mm	30 - 35

Preliminary State Assessment
States of Raynaud's Phenomenon (VWF)

Stages	Condition of Digits	Work and Social Interference		
0	No blanching of digits	No complaints	[ ]	36
0_T	Intermittent tingling	No interference with activities	[ ]	37
0_N	Intermittent numbness	No interference with activities	[ ]	38
1	Blanching of one or more fingertips with or without tingling and numbness	No interference with activities	[ ]	39
2	Blanching of one or more fingers with numbness. Usually confined to Winter	Slight interference with home and social activities. No interference at work	[ ]	40
3	Extensive blanching. Frequent episodes Summer as well as Winter	Definite interference at work, at home and with social activities. Restriction of hobbies.	[ ]	41
4	Extensive blanching. Most fingers; frequent episodes Summer and Winter	Occupation changes to avoid further vibration exposure because of severity of signs and symptoms	[ ]	42

(Note: Complications are not used in this grading.)

COMMENTS: _____

Examining Physician _____ Date _____

First 3 Characters of Last Name [ ][ ][ ] 75 - 77

MEDICAL QUESTIONNAIRE

KEYPUNCH INSTRUCTIONS

CARD NO. 1

MEDICAL CODING SHEET

		Card Columns
Case Number	☐☐☐☐	1 - 4
Blood Pressure		
	Right Arm / Left Arm	
Sys.	☐☐☐ / ☐☐☐	6 - 11
Dia.	☐☐☐ / ☐☐☐	12 - 17
Pulses		
	Right / Left	
Radial	☐ / ☐ 0 = Nothing Felt	18 - 19
Brachial	☐ / ☐ 1 = Just Perceptible	20 - 21
Dorsalis Pedis	☐ / ☐ 2 = Normal 3 = Increased 4 = Greatly Increased	22 - 23
Tibialis Ant.	☐ / ☐	24 - 25
Heart		
Rate	☐☐☐ Beats/Minute	26 - 28
Rhythm	☐ 1 = Regular 2 = Irregular	29
Murmurs	☐ 0 = Absent 1 = Present	30

Arms	LFA	LBA	RFA	RBA	
Significant Trauma	☐	☐	☐	☐	31 - 34
Scars	☐	☐	☐	☐	35 - 38
Deformities	☐	☐	☐	☐	39 - 42
Skin Lesions	☐	☐	☐	☐	43 - 46
Needle Marks	☐	☐	☐	☐	47 - 50

0 = Absent 1 = Present

Card No. 01 **79 - 80**

CARD NO. 2

		Card Columns
Case Number	☐☐☐☐	1 - 4

Hands (Palm and Dorsum)

	LP	LD	RP	RD	
Trauma	☐	☐	☐	☐	6 - 9
Blanching	☐	☐	☐	☐	10 - 13
Cyanosis	☐	☐	☐	☐	14 - 17
Hyperaemia	☐	☐	☐	☐	18 - 21
Skin Lesions	☐	☐	☐	☐	22 - 25
Scars	☐	☐	☐	☐	26 - 29
Lacerations	☐	☐	☐	☐	30 - 33

0 = Absent 1 = Present

Callus	☐☐☐☐	34 - 37

0 = None 1 = Mild 2 - Moderate 3 = Severe

Card No. 02	79 - 80

CARD NO. 3

DIGITS

Case Number ☐ ☐ ☐ ☐ — Card Columns 1 - 4

	AMP.	BLA.	CAL.	CYN.	F.T.U.	J.S.	K.P.	SC.-LA.	TR.-FRA.	F.S.	
LDTP											6 - 15
LDTD											16 - 25
LD11											26 - 35
LD12											36 - 45
LD13											46 - 55
LD21											56 - 65
LD22											66 - 75
Card No. 03											79 - 80

CARD NO. 4

Case Number ☐ ☐ ☐ ☐ — 1 - 4

	AMP.	BLA.	CAL.	CYN.	F.T.U.	J.S.	K.P.	SC.-LA.	TR.-FRA.	F.S.	
LD23											6 - 15
LD31											16 - 25
LD32											26 - 35
LD33											36 - 45
LD41											46 - 55
LD42											56 - 65
LD43											66 - 75
Card No. 04											79 - 80

CARD NO. 5

Case Number ☐ ☐ ☐ ☐

Card Columns 1 - 4

	AMP.	BLA.	CAL.	CYN.	F.T.U.	J.S.	K.P.	SC.-LA.	TR.-FRA.	F. S.	
LVTP											6 - 15
LVTD											16 - 25
LV11											26 - 35
LV12											36 - 45
LV13											46 - 55
LV21											56 - 65
LV22											66 - 75

Card No. 05 79 - 80

CARD NO. 6

Case Number ☐ ☐ ☐ ☐

1 - 4

	AMP.	BLA.	CAL.	CYN.	F.T.U.	J.S.	K.P.	SC.-LA.	TR.-FRA.	F.S.	
LV23											6 - 15
LV31											16 - 25
LV32											26 - 35
LV33											36 - 45
LV41											46 - 55
LV42											56 - 65
LV43											66 - 75

Card No. 06 79 - 80

CARD NO. 7

Case Number ☐ ☐ ☐ ☐ — Card Columns 1 - 4

	AMP.	BLA.	CAL.	CYN.	F.T.U.	J.S.	K.P.	SC.-LA.	TR. -FRA.	F.S.	
RDTP											6 - 15
RDTD											16 - 25
RD11											26 - 35
RD12											36 - 45
RD13											46 - 55
RD21											56 - 65
RD22											66 - 75

Card No. 07 — 79 - 80

CARD NO. 8

Case Number ☐ ☐ ☐ ☐ — 1 - 4

	AMP.	BLA.	CAL.	CYN.	F.T.U.	J.S.	K.P.	SC.-LA.	TR.-FRA.	F.S.	
RD23											6 - 15
RD31											16 - 25
RD32											26 - 35
RD33											36 - 45
RD41											46 - 55
RD42											56 - 65
RD43											66 - 75

Card No. 08 — 79 - 80

CARD NO. 9

Case Number ☐☐☐☐ Card Columns 1 - 4

	AMP.	BLA.	CAL.	CYN.	F.T.U.	J.S.	K.P.	SC.-LA.	TR.-FRA.	F.S.	
RVTP											6 - 15
RVTD											16 - 25
RV11											26 - 35
RV12											36 - 45
RV13											46 - 55
RV21											56 - 65
RV22											66 - 75

Card No. 09 79 - 80

CARD NO. 10

Case Number ☐☐☐☐ 1 - 4

	AMP.	BLA.	CAL.	CYN.	F.T.U.	J.S.	K.P.	SC.-LA.	TR.-FRA.	F.S.	
RV23											6 - 15
RV31											16 - 25
RV32											26 - 35
RV33											36 - 45
RV41											46 - 55
RV42											56 - 65
RV43											66 - 75

Card No. 10 79 - 80

0 = Absent 1 = Present EXCEPT FOR CALLUS
For Callus: 0 = None 1 = Mild 2 = Moderate 3 = Severe

CARD NO. 11

				Card Columns
Case Number	☐☐☐☐			1 - 4
Mobility	Flex.	Ext.		
Wrist	☐	☐	1 = Normal	6 - 7
Fingers	☐	☐	2 = Abnormal	8 - 9
Tendonitis		☐		10
Carpal Tunnel Syndrome		☐	1 = No	11
Dupuytren's		☐	2 - Yes	12
Arthritis		☐		13
Preliminary Stage Assessment	☐☐☐			14 - 16

Stage Assessment	Code Entered Into Blocks
0	0
0_T	0 T
0_N	0 N
0_{TN}	0 T N
1	1
2	2
3	3
4	4

Hand on Chisel ☐ 17

1 = Left 2 = Right 3 = Both

Card No. 11 79 - 80

APPENDIX D

CODE DESCRIPTIONS AND FREQUENCIES FOR CODED OCCUPATIONAL HISTORY AND HOBBY VARIABLES

TOOLS FOR JOBS

TOOL NAMES	FREQUENCY
Air Chisel	1
Air Tools for Mechanics	1
Air Drill; Grinders	1
Air Grinder	17
Air Gun	6
Air Hammer; Drill	2
Air Hammer; Grinders	292
Air Hammer; Grinders; Pneumatic Saws; Pneumatic Drills	17
Air Hammer; Pencil Grinders	7
Air Tampers	2
All Pneumatic Tools	5
Pneumatic Tools; Grinders; Sanders	1
Air Wrench	5
Buffer; Drill	1
Chipper; Drills; Saw	3
Chipping Hammer; Saws; Grinders; Riveting Hammer	2
Chipping Hammer; Grinder; Planer; Chisel	1
Chain Saw	1
Chipper; Grinder; Drills	14
Chipper; Grinder; Drill; Sander	1
Chipper; Grinder	48
Chipping Hammer; Grinders; Saws	21
Chipping Chisels	3
Chipping Gun	2
Chipping Hammer	14
Chipper; Drill; Impact Wrench	3
Chipper; Grinder; Saw; Sander	1
Electric Drill	2
Electric Impact Drill; Jackhammer	1
Electric Drill; Saw	2
Electric Nut and Bolt Remover	1
Electric Saw; Jackhammer	1
Chipper; Grinder; Riveter	1
Electric Riveter	1
Grinder; Drill; Saw	1
Grinder; Needle Gun; Deck Crawler	1
Electric Saw	1
Grinders; Saws	1
Grinders	12
Grinders; Drills	6
Hand Chisel	1

TOOL NAMES	FREQUENCY
Fine Grinders	1
Hydraulic and Air Machine	1
Impact Wrench; Chipper	3
Impact Wrench; Grinders; Drills	2
Impact Wrench	7
Impact Wrench; Chipper; Grinder	2
Impact Wrench; Chipper; Grinder; Sander	1
Impact Wrench; Grinder	1
Jackhammer	22
Jackhammer; Chipper; Drills	1
Machine Gun	1
Jackhammer; Drill	1
Jackhammer; Chipper; Grinder	1
Needle Guns; Bumble Bees; Buffers	1
Pneumatic Drill	2
Pneumatic Lug Remover	1
Pneumatic Hammer; Drill	1
Riveting Hammer; Drill	1
Riveting Hammer; Chipper; Grinder; Saw; Drill	1
Router; Sander; Planer	1
Router; Sander	1
Sander	3
Tamping Hammer; Grinder; Chipper	1
Tamper	1
Torque Gun	1
Vibrators to Pack Ground	3
Air Hammer; Cement Vibrator	1
Air Hammer; Air Tamper	2
Skill Saws; Air Hammer	1
Power Shread; Cement Vibrator	1
Air Drill; Air Nail Gun	1
Pneumatic Brushes	1
Grinders; Rebarcutter	1
Grinder; Air Chisel	1
Jackhammer; OMC Machine	1
Scaling Hammer; Chipping Hammer; Air Tools	1
Cement Drill; Impact Wrench; Roto Hammer	1

JOB TITLE

JOB TITLE	FREQUENCY
Abr. Rh. Blst. Opr.	1
Aircraft Handler	1
Aircraft Maintenance	1
Appr. Pipe Fitter	1
Assembler	7
Asst. Foreman	1
Attendant	2
Auto Mechanic	5
Automatic Screw Mach. Opr.	74
Auto. Cutoff Machine Opr.	1
Aviation Elec. Tech.	1
Bench/Floor Hand	2
Boiler Maker	11
Boiler Opr.	1
Carpenter	4
Casting Salvage	38
Cement Finisher	1
Chip/Grind Heavy	59
Chip Intricate	94
Chip and Grind	130
Chipper/Caulker	3
Cleanup	1
Combat Engr.	2
Construction Worker	1
Core Maker	2
Disassembly	1
Driller	2
Electronics	1
Driver	1
Engineer/Gunner	1
Electrician	4
Fitter	3
Flask Repair	1
Foreman	2
Forester	1
Fine Control Appr.	1
Foundry Worker	2
Forklift Truck Driver	1
Inspector	1
Helper	2
Hand Cleaner	2

JOB TITLE	FREQUENCY
Heavy Equip. Opr.	1
Hull Maint. Tech.	1
Installers	3
Iron Worker	1
Laborer	37
Lathe	1
Lay-Out	3
Leadman	1
Machine Opr.	1
Machine Tool Opr.	3
Machinist	6
Maint. Helper	1
Manager	1
Materials Handler	5
Mechanic	6
Millwright	2
Molder	2
Moulding	1
Mover	1
N.C. Opr.	1
Painted Tr. Svcmn.	2
Painter	1
Planer	1
Pneumatic Super.	2
Punch Press Opr.	1
Parts Handler	1
Propeller Finisher	31
PTO (Pneumatic Tool Opr.)	41
Pipe Fitter	6
Radial Driller	1
PTO Test Spclst.	7
PTO Test Spec. FM.	1
PTO Instructor	1
Reclaimer	1
Rigger	8
Rod Straightener	1
Sand Mixer	1
Shaving Hauler	1
Seaman	3
Sgt.	1
Sect. Foreman	1
Sheet Metal Mechanic	2
Ship Wright	3
Ship Fitter	5
Siding Applicator	1
Tank Specialist	2
Test Specialist	2
Tire Man	1
Tool Room Mach.	1
Supervisor	1

JOB TITLE	FREQUENCY
Sheet Metal Worker	2
Truck Driver	3
Utilities	1
Welder	6
Well Cleaner	1

DEPARTMENT NUMBER

DEPARTMENT NUMBER	FREQUENCY
4	1
6	56
7	3
8	2
9	3
10	22
11	1
12	1
13	80
14	7
16	1
20	2
21	1
22	4
24	6
28	1
29	8
32	1
33	1
36	1
39	9
40	1
44	1
52	1
56	50
60	2
64	26
68	3
72	22
76	3
80	1
84	1
86	1
88	1
90	1
91	1
92	1
93	1
94	1

DEPARTMENT NUMBER	FREQUENCY
95	1
96	2
100	27
104	106
108	33
112	1
116	1
117	1

TYPE OF COMPANY

COMPANY	FREQUENCY
Air Conditioning	1
Aluminum Mfg.	1
Automobile Mfg.	1
Body Shop	2
Boiler Repair	1
Elevator Mfg.	1
Hog. Building Mfg.	1
Stg. Building Mfg.	1
Carwash Equipment Mfg.	1
Casting Pumps	1
Cement Contractor	5
City Government	1
Concrete	3
Construction	24
Crane Operation	1
Drywall Construction	1
Electric Instal.	6
Electrical Engineering	1
Engineering	2
Fence Construction	1
Formica Mfg.	1
Foundry	6
Gas Station	4
General Contractor	1
Graphics	1
Grain Bins	1
Helicopter Mfg.	1
Iron Works	2
Hot Water Heater Mfg.	1
Locomotive Operation	3
Machine Shop	1
Machinery Mfg.	1
Locomotive Parts Mfg.	1
Crane Mfg.	1

COMPANY	FREQUENCY
Tractor Mfg.	1
Wagon Mfg.	1
Masonry	1
Heavy Equipment Mfg.	3
Muffler Instal.	1
National Guard	1
Oil Production	2
Painting	1
Pavement	1
Pipe Mfg.	1
Pre-Fab Houses	1
Propellor Mfg.	9
Radiator Mfg.	1
Railroad's Operation	2
Refrigerator Mfg.	1
Road Construction	2
School	1
Ship Building	13
Steam Turbine Mfg.	1
Steel Mfg.	6
Tool and Dye	1
Tractor Foundry	1
Tree Service	1
Truck Mfg.	2
U.S. Air Force	3
U.S. Army	2
U.S. Coast Guard	2
U.S. Navy	8

HOBBY

HOBBY NAME	FREQUENCY
Auto Body Work	1
Auto Work	2
Carpentry	4
Cutting Logs	3
Cutting Trees	1
Farm	1
Firewood	1
Home Repair	2
Mechanic	1
Model Railroads	1
Motor Repair	1
Race Cars	1
Refinish Wood	2
Wood Work	14

HOBBY TOOLS

HOBBY TOOLS	FREQUENCY
Air Chisel	1
Pneumatic Tools; Grinders; Sanders	1
Air Wrench	1
Chain Saw	5
Electric Drill	1
Electric Drill; Saw	1
Electric Saw	2
Electric Saw; Electric Drill; Router	1
Chisel; Drill; Saws	1
Grinder; Saw; Drill; Lathe	1
Impact Wrench; Electric Saw	1
Motor	1
Pneumatic Drill	1
Saber Saw	1
Saber Saw; Ban Saw; Sander Saber Saw; Electric Drill	1
Chain Saw; Saber Saw; Skill Saw	1
Sander	6
Sander; Power Saws	1
Sander; Drills	1
Sander; Saw; Drills	1
Sander; Saber Saw	1
Skill Saw	2

APPENDIX E

TOOLS USED BY EXPOSED WORKERS ON CURRENT JOBS, PAST JOBS WITH PRESENT EMPLOYERS, AND PAST JOBS WITH PAST EMPLOYERS (EXPOSURE GROUP 1 ONLY)

CURRENT JOBS (EXPOSURE GROUP 1)

TOOLS	PERCENT OF CURRENT JOBS: FOUNDRIES 1 & 2 (N=159)*	PERCENT OF CURRENT JOBS: SHIPYARD (N=76)*
Chipping Hammers	99	96
Pneumatic Grinders	99	92
Pneumatic Drills	0	58
Pneumatic Saws	0	57
Pneumatic Impact Wrench	0	4
Pneumatic Riveting Hammer**	0	4
Pneumatic Sander	0	3
Planer	0	1
Pneumatic Tamping Hammer (not the same as an air tamper; this is a chipping hammer with a tamper inserted instead of a chisel)	0	1

* Total number of current jobs; also total number of workers in these groups.

** Subject to some restrictions; see definition of exposure group 1 in Occupational Histories and Exposure Groups.

PAST JOBS WITH PAST EMPLOYERS (EXPOSURE GROUP 1)

TOOLS	PERCENT OF PAST JOBS WITH PAST EMPLOYERS	
	FOUNDRIES 1 & 2 (N=41)*	SHIPYARD (N=58)*
Pneumatic Grinders	81%	72%
Chipping Hammer	32	72
Pneumatic Impact Wrench	12	10
Jackhammer**	10	0
Pneumatic Drill	7	0
Electric Saw	5	0
Air Tamper**	2	0
Electric Drill	2	2
Sander	2	7
Skill Saw	2	0
Cement Vibrator	2	0
Air Nail Gun	2	0
Scaling Hammer	2	0
Cement Drill	2	0
Roto Hammer	2	0
Pneumatic Saw	0	3
Pneumatic Riveting Hammer**	0	3
Needle Gun	0	2
Pneumatic Lug Remover	0	2
Router	0	3
Planer	0	3

* Total number of past jobs with past employers.

** These tools were subject to some restrictions; see the definition of exposure group in Occupational Histories and Exposure Groups.

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PAST JOBS WITH PRESENT EMPLOYERS (EXPOSURE GROUP 1)

TOOLS	PERCENT OF PAST JOBS WITH PRESENT EMPLOYERS	
	FOUNDRIES 1 & 2	SHIPYARD
	(N=75)*	(N=16)*
Chipping Hammers	97%	63%
Pneumatic Grinders	96	81
Pneumatic Impact Wrench	1	0
Pneumatic Drills	0	19
Pneumatic Saws		13
Electric Drill		6

* Total number of past jobs with present employer.

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