RAYNAUD'S PHENOMENON IN GRINDERS OF SMALL METAL CASTINGS

A CLINICAL AND EXPERIMENTAL STUDY

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The clinical picture, now generally known as Raynaud's phenomenon, of intermittent pallor or cyanosis of the extremities precipitated by cold yet without evidence of blockage of the main peripheral vessels, can be brought about by a number of aetiological factors. There is no longer any doubt that vibration is one of these, even if the manner of its action is still uncertain. Pneumatic tools have for a long while been known to produce this syndrome in the hands after a latent period of some 2 to 5 years of working, and a number of clinical studies of the condition have been completed. It has been noted that right-handed men usually hold their pneumatic tool with the right hand on the handle at the back, and the left hand in front near the working end of the tool where it is subjected to the greater vibration. It is this left hand which is usually first and most extensively affected, even when protected with a glove. Moreover, though cold is in these cases a precipitating factor, it is not necessarily the cold exhaust air from the tool that is responsible, because this may be directed backwards towards the right hand, which may nevertheless be unaffected. A recent paper by Telford, McCann and MacCormack (1945) again suggests that it is the vibrations that are primarily responsible, for they describe the phenomenon occurring after the use of a small portable scurfing or grinding tool driven by a flexible cable drive from a suspended electric motor. The grip employed on the hand-piece of this tool is usually an overhand grip with the left hand and an underhand with the right, the left being in front. When using the tool they describe, the impression is gained that the left hand is subjected to rather more vibration than the right, and more pressure is needed with this hand to hold the rotating cutting-head against the metal to be worked upon. The left hand once more is the first affected, after an average delay of two years and three months from starting to use the tool, regardless of the age of the worker.

A number of typical examples of the Raynaud phenomenon have been observed in the last two years in the grinding shop of an iron and steel foundry in the home counties. In these cases the vibration is transmitted from the grinding surface to the hands via the articles being ground, and not because of the use of any portable tool which itself vibrates. It is the purpose of this paper to describe the

clinical findings in a number of such cases and the results of an analysis of the type of vibration encountered.

The Method of Grinding

The foundry produces a number of iron components of various shapes and sizes which constitute the angle, T-piece, and joining connections for systems of iron piping. The rough castings come to the grinding shop to have the runners and other excess metal removed from the lines where the two halves of the casting mould were joined. This grinding takes place prior to machining and galvanizing. Some of the components are to fit pipes of some 4 inches internal diameter, but most of them are smaller, of $\frac{3}{4}$ inch internal diameter or less. They are ground against large plastic-bonded carborundum wheels, most of which are belt-driven; a few are on electrically driven spindles. The heavier work is mainly done by men, but for some of the lighter work and most of the final grinding on the electrically operated wheels women have of late been employed. All the wheels are of comparable diameter, and different sizes of pulleys allow of three speeds of drive to enable an increase in the revolutions to be made as the wheel becomes worn, to maintain the surface speed at the optimum figure. The thickness of the wheel is usually either $2\frac{1}{4}$ inches for the larger pieces and the outer surfaces, or of $\frac{1}{4}$ to $\frac{3}{8}$ inch for the less accessible internal angles. The speeds for a typical one of the thicker wheels vary between 730, 912, and 950 r.p.m., the alterations being made as the wheel wears down to diameters of 30, $24\frac{1}{2}$ and 20 inches respectively. This means that the velocity of the grinding surface varies between the limits of 4970 and 5840 surface feet per minute. For a narrow wheel the revolutions are initially 1950 per minute to correspond to a diameter of 16 inches, and finally 3050 per minute to correspond with 8 inches diameter. The limits are in this case 6390 to 8180 surface feet per minute. The electrically operated wheels are of $1\frac{1}{2}$ and 3 inches thickness and work respectively at 7310 to 9180, and 2590 to 6650, surface feet per minute.

The workman stands at his wheel with a tray of rough castings within easy reach to his left and an empty tray to his right into which he tosses the

finished components. As the work is piece-work he will achieve considerable manual dexterity in handling them, and can grind one piece, sides and ends, in some two or three seconds. He grips it firmly between thumb and index finger of each hand; he may use the middle finger also in handling the larger pieces, but the remaining fingers usually rest lightly on an adjustable steel bench or anvil (fig. 1)

FIG. 1.—General view of belt-driven grinding equipment, showing adjustable steel bench, various tongs, and a tray of ground components.

close to the wheel, and are seldom in direct contact with the metal being ground. The main downward pressure is taken by this fixed bench, but the horizontal pressure for pushing the casting against the wheel is provided by his fingers, and in particular the terminal portion of the thumb. The work may only be in contact with the wheel for less than a second at a time, but during this time an intense vibration is set up. The manoeuvres are repeated many hundreds of times in an hour, and the men have averaged a 50-hour week. A man may elect to wear gloves while grinding, but this is unusual. Alternatively he may bind his thumbs and index fingers with strips of cloth, but he does so with a view to lessening the risk of trauma to his fingers or burns from the heat of the grinding process, and not to reduce the vibrations.

Some of the men have worked at a broad wheel or a narrow one for the whole of their employment, but several have changed from time to time. Each man is liable to change the type of component he

grinds almost from hour to hour. In handling the smaller ones he may choose to use a pair of rough metal tongs with which to grip the wall of the hollow casting; the tongs are held in the palm of the right hand. Most of them prefer to use these tongs as in this way greater control is obtained, and again the risk of trauma and burning of the fingers is lessened. To press components on to the broader wheels more effort is needed, and the man is provided with a wooden 'crutch', of which one end fits into a slot in the back of the metal bench and the other rests against his upper abdomen, being steadied there with his left hand from time to time

FIG. 2.—Method of holding a larger angle component in the hands for grinding its outer surface.

(fig. 3). By leaning forwards on this crutch he may use his weight to press the casting forwards, and he has one hand relatively free. Use of the crutch clearly lessens the quantity of vibration transmitted to his fingers. From time to time while working a man finds the surface of his wheel has become too rough, and he dresses it for a few seconds by grinding a special serrated tool of hard steel.

The grinding shop is airy and well ventilated, but noisy. It is usually warm, and the men are naturally handling warm articles all day since the grinding process makes them so. Goggles for protection against flying fragments are invariably worn.

FIG. 3.—Showing the use of the tongs and the 'crutch'.

Clinical Findings

No intentional selection of cases was made. All members of the grinding shop who would consent were interviewed, whether or not they were known to exhibit Raynaud's phenomenon. Only one or two refused. Workers who had worked at grinding previously but who had since changed their occupation within the same works were also included. This change had in one or two instances been made at the medical officer's recommendation, as a result of complaints of 'dead fingers', but in other cases the events were unconnected. It was noticed throughout the investigation that the workers were in general very little concerned with their lesions in spite of the fact that several of them suffered some inconvenience. In most cases they had not bothered to complain to the doctor previously, but they had named the condition 'grinders cramp' amongst themselves and attributed it to the tight gripping of castings.

A full occupational history was taken, also a routine medical history in which particular regard was paid to previous vascular disturbances, or any familial incidence of these. Clinical examinations followed, and each individual was subjected to a water immersion test, being made to sit for fifteen minutes with the arms below the level of the heart, immersed to above the elbows in water which was kept as nearly as possible to 15° C., after which the distribution of pallor or cyanosis in the fingers was noted.

In all 37 workers were seen, 29 men and 8 women, and of the 29 men, there were 27 who showed the phenomenon and 2 who did not, while of the 8 women, 5 showed it and 3 did not. These figures result from considering the claims of the individuals and not from the outcome of the immersion test. Of the two negative male cases, one was aged 21 and had worked in the grinding shop for 1 year, while the other was 51 years old, had worked in this grinding shop for 6 years, and had 13½ years of similar work to his credit. The negative cases amongst the women were aged 35, 21, and 42, and had worked respectively for 6 months, 1 year, and 3 years and 9 months on the smaller of the electrically driven wheels. Of the positive male cases the first gave a self-contradictory history, and it was thought advisable to exclude his figures from the analysis.

All the workers were right-handed except for one man and one woman. Considering the positive cases, the age limits for the men were 29 to 50 with a mean of 37, while the age limits for the women were 24 to 45, with a mean of 36 years. The average duration of working for all of the positive cases was 5 years and 3 months at the time of the questioning; the limits were wide, lying between 1 and 12 years. Assessing the time that elapsed between starting this work and the onset of symptoms the average was 1 year and 9 months, though the limits were 0 to 7 years. In this connection it is as well to note, first, that a man may find much more difficulty in stating how long his symptoms have been present

than he will in remembering the duration of his employment; the last figures therefore tend to be inaccurate. Secondly, two of the men reported that the symptoms first came on before they ever started work at grinding, at 2 and 2½ years before respectively. The reason for this is obscure and may perhaps point to a general increase of vascular disturbances of this type amongst the population during recent years, but the high incidence amongst the 37 people comprising this present series is clearly too much to be explained by this means. In neither of these last two unusual cases was there evidence that previously the men had used vibrating tools or had done grinding work.

On direct questioning two workers gave a previous history of having suffered from deadness of the fingers earlier in life, but in neither case did the severity or distribution appear to correspond with that after grinding work had begun. None would admit to any similar disease in his family; in a series of 37 that is perhaps questionable, but is probably due to faulty observation. Three of the men had previously done work with grinding wheels but on different castings and in different circumstances; the figures in their cases are therefore included, though the possibility that this previous work influenced their present condition is not denied. One of them was remarkable for being in the negative group with a total of 19½ years of service at grinding in various forms. The second had had 10 years experience of grinding and fettling previously, yet had only developed the syndrome 2 years after starting work in this grinding shop. The third had had a year of grinding nearly 10 years previously, but here again the onset of symptoms had been 2 years after beginning his present job.

In 2 cases the right hand had been affected first, in 11 the left; in the 18 others the onset was in both hands simultaneously. One left-handed worker had her left hand affected first, the other had both his at once. Of those originally affected in one hand only, six said that eventually both were involved, so that ultimately 23 out of the 31 admitted to bilateral lesions, with a tendency for the left to be involved first. All were found to be able to indicate

TABLE I
DISTRIBUTION OF RAYNAUD'S PHENOMENON IN 31 CASES

Extent	Right hand					Left hand				
	Th.	II	III	IV	V	Th.	II	III	IV	V
Tip to distal interphalangeal joint	—	19	18	16	13	—	22	27	23	18
Tip to proximal interphalangeal joint	6	17	15	14	10	9	20	24	21	14
Tip to metacarpophalangeal joint	1	6	5	4	5	2	10	8	5	5

with fair certainty how far down the fingers the lesion usually spread, for, as is usual in this condition, in any affected fingers the tips were invariably involved and the pallor would extend proximally. The workers were asked to estimate the extent of their lesions in terms of joints of the fingers, and the results are given in Table 1, which is based on statements and not on the immersion test.

Cyanosis in place of pallor or following upon it

was admitted by 8 patients, but denied in 23. In the 8 cases there was insufficient evidence to show whether cyanosis can be considered a sign of later onset than pallor, or whether cyanosis can be considered to indicate a lesion of particular severity. The distribution in terms of number of digits affected was so wide that it did not suggest this either. In all cases it was confirmed that cold conditions precipitated an attack, and in no case

TABLE 2
SUMMARY OF THE CLINICAL FINDINGS IN 37 GRINDERS

Case No.	Sex	Age	R. or L. handed	Years employed at this type of grinding	Onset of Raynaud's from start of this occupation (years)	Type of wheel	Hand of onset	Present distribution		Cyanosis claimed	Onset at work claimed	Some disability
								Right hand	Left hand			
1	M	17	R	5/12	1/12	Large	R	2'''3'''	—	—	+	—
2	M	32	R	6	1	Small	R	2''3''4''	—	—	—	+
3	M	39	R	22/12	17/12	Large	L	—	3''4''	—	+	—
4	M	41	R	2	0	Large	R & L	2' 3' 4'	2' 3' 4'	—	+	+
5	M	42	R	58/12	28/12	Small	R & L	1' 2'''3'''4'''5'	1' 2'' 3''4''5'	+	—	—
6	M	33	R	59/12	1	Large	R & L	1' 2'''3'''4'''5'	1' 2'' 3''4''5'	—	—	—
7	M	50	R	6	2	Large	R & L	2'''3'''4'''5'''	2'' 3''4''5''	—	+	+
8	M	32	R	6	?	Small	L	—	2'''3'''4'''5'	+	—	+
9	M	41	R	2	?	Both	L	—	1' 2'''3'''	+	+	—
10	M	38	R	16/12	11/12	Small	R & L	4'	1' 2''	+	—	—
11	M	36	R	1	4/12	Small	R & L	2'''	1' 2'''	—	—	—
12	M	33	R	7	6/12	Large	R & L	2'''3'''4'''5'''	2'''3'''4'''5'''	+	+	+
13	M	29	R	2	0	Large	R & L	5'	3'4'5''	+	—	—
14	M	21	R	1	—	Both	—	—	—	—	—	—
15	M	51	R	6	—	Both	—	—	—	—	—	—
16	M	34	R	66/12	2	Small	L	—	2' 3'	—	+	—
17	M	42	R	66/12	2	Large	R & L	3'' 4'' 5''	3'' 4'' 5''	+	+	+
18	M	43	R	116/12	2	Small	R & L	3' 4'' 5'''	3' 4'' 5'''	+	—	—
19	M	31	R	56/12	46/12	Large	L	3''	2'' 3''4''5''	—	+	+
20	M	38	R	12	7	Large	R	2'''3'''4'''5'''	2'''3'''4'''5'''	—	+	+
21	M	38	L	59/12	13/12	Large	R & L	2'' 3'' 4''	2'' 3'' 4''	—	—	—
22	M	34	R	11	1	Large	R & L	1''2'' 3'' 4'' 5''	1''2'' 3'' 4'' 5''	—	—	+
23	M	30	R	86/12	16/12	Small	L	2'' 3'' 4'' 5''	2'' 3'' 4'' 5''	—	—	+
24	M	40	R	116/12	6/12	Large	R & L	2'''3'''4'''5'''	2'''3'''4'''5'''	—	+	+
25	M	35	R	5	1	Both	R & L	1' 2'''3'''4'''5'''	1' 2'''3'''4'''5'''	—	+	+
26	M	39	R	1	6/12	Large	L	2' 3'	3'' 4'' 5''	—	+	—
27	M	41	R	4	1	Small	L	—	2'''3'''4'''	—	+	—
28	M	34	R	2	1	Large	R & L	2''	3''	—	+	+
29	M	41	R	8	2	Small	L	—	3''4''5''	—	+	—
30	F	40	R	3	16/12	Small	R & L	2'''3'''	2'''3'''	—	+	—
31	F	39	R	39/12	19/12	Small	R & L	1' 2'' 3''4''5''	1' 2'' 3''4''5''	—	+	+
32	F	24	R	26/12	110/12	Both	L	—	3''4''	—	+	+
33	F	32	R	26/12	1	Small	R & L	2''	2''	—	—	—
34	F	45	L	4	1	Both	L	1' 2''	1' 2'''3'''4''' 5'	—	+	—
35	F	35	R	6/12	—	Small	—	—	—	—	—	—
36	F	21	R	1	—	Small	—	—	—	—	—	—
37	F	42	R	39/12	—	Small	—	—	—	—	—	—

(Note 1.—For convenience in describing the present distribution the convention is used that the number of strokes following the number of the digit indicates the anatomical spread of the lesion, according to Table 1.
2.—Case No. 1 excluded from final analysis—see text.)

was it admitted that attacks came on under stress of emotion. One man said that he had pain during the attacks, another complained of pain if he continued to work during an attack, while two others talked of a dull ache. There were a number who described a painful tingling sensation as the blood returned to the affected fingers. Fifteen patients said that attacks could come on while they were working; 13 denied that this ever happened though they were often affected in the early morning on rising; 3 others had attacks at the start of a day's work but thereafter were not troubled. The duration of individual attacks appeared to vary between 10 and 180 minutes, but this was at best given in round figures, many saying that the attacks lasted until their hands became warm again. There was little evidence to suggest either that a widespread lesion tended to have a long duration, or the converse.

The disability caused to the workers was very difficult to assess, though generally it was minimized, and anxiety as to the future was very rarely seen. Some inconvenience was alleged by 15 people, 11 of these being amongst those whose attacks came on while working; 4 claimed some disability even though attacks were not apparent at work. There was no evidence of the loss of whole days of work from this cause, but in a few cases a man might lose an hour or two through having to wait while his hands warmed up, a point of some significance in piece-work. There were 12 who had for various reasons given up grinding; three of them denied any improvement as a result though they had stopped for 2 months, 1 year, and $5\frac{1}{2}$ years respectively. The remainder claimed some degree of improvement, and in one case attacks had ceased 1 year after stopping the work. In most cases it was not possible to define a man's evidence for claiming he was improved. It seems likely that if questioned at the end of the summer more people will admit improvement than at the end of the winter.

There were few abnormal physical signs to see. Two men had a mild degree of hypertension with a systolic blood pressure of 170 mm. Hg. One was aged 33, and had extensive bilateral involvement of his fingers which came on after a year of this work, while the other was aged 38 and had slight involvement coming on 11 months after starting. In two cases there were punctate and linear burn scars extending up both forearms from the showers of burning sparks that are given off in grinding. In one or two cases there were unusually placed callosities, but there was no evidence of trophic or neurological changes in the fingers.

The water immersion test yielded little additional information, but had to be done on a warm day under conditions that were difficult to control. In 21 of the cases pallor or cyanosis was produced, and in 10 others who alleged they had the disease there was nothing abnormal to see, though 2 of these had claimed extensive lesions. In most cases the water test produced signs that were less

extensive than those claimed, and the impression gained was that in the conditions of a factory first aid station there are too many variable factors to make the test of much value, and that it ought not to be used as a diagnostic test of a man's claims in cases of dispute.

The cases were found to be divisible into three groups, those where the larger grinding wheels had been used throughout, those where the smaller, and those where there had been a change from one to the other. If the extent of the lesion is expressed in terms of the number of portions of finger involved, according to Table 1, and if extent of lesion can be assumed to give some measure of severity of a particular case, some correlation might appear between severity of the lesion and the type of grinding done on the large or the small wheels, provided that in the two groups there is no great discrepancy between ages or periods of service. Taking into consideration both negative and positive cases, there are 16 who used the small wheels, 14 who used the large, and 6 who had used both at various times. The average age of those who used the small was 36.1, and of those who used the large 37.2. The scatter is shown in the following table.

TABLE 3

Age group	Large wheel	Small wheel
Under 30 ..	1	1
30-34 ..	5	5
35-39 ..	4	4
40-44 ..	3	6
45 and over ..	1	0
Total	14	16

The two groups are therefore reasonably comparable as regards age. Further analysis then shows :

TABLE 4

Grinders using:	No. of obs.	Length of employment		Areas affected	
		Mean	Standard deviation	Mean	Standard deviation
Small wheel ..	16	4.58	3.00	7.69	5.72
Large wheel ..	14	5.73	3.58	13.36	7.13

This indicates, in spite of the fact that the numbers are small and the standard deviations large, that there is a difference between the means of the portions of digits affected (i.e. the 'severity' of the lesions) of $13.36 - 7.69 = 5.67$. There is a small difference between the mean length of employment

TABLE 5

Duration of employment in years	Mean Values								
	Small wheel			Large wheel			Both wheels		
	No.	Age	'Severity'	No.	Age	'Severity'	No.	Age	'Severity'
Under 3	5	32.4	3.2	5	36.4	5.8	3	28.7	3.3
3-5	5	40.8	11.0	3	34.0	12.7	2	40.0	19.5
6 and over	6	35.3	8.7	6	39.5	20.0	1	51.0	0

in the two groups, but scarcely enough to account for this difference in 'severity'. The difference of 5.67 between the means is more than would have been likely to have arisen by chance (P lying between 0.05 and 0.02 with the 't' test). This may indicate that the kind of work done with the larger wheels causes a more extensive distribution of the lesion than the kind done with the smaller.

It was found on questioning the workers that some would admit that the lesions had got progressively more extensive, some denied this, but a high proportion were uncertain. An attempt was therefore made to settle the point on statistical evidence. Taking, in Table 5, three groups according to duration of employment at this form of grinding, and considering the means of the ages and of the 'severity' expressed as before in terms of the number of portions of digits affected, the analysis appears as above.

This suggests that there is some evidence in the case of grinding operations on the large wheels that the severity of the lesion depends on the duration of a man's employment. The possibility of age affecting this issue cannot be quite excluded. Taking together the employees on small and large wheels, there is a correlation coefficient between the individual duration of employment and the index of severity of +0.65; this is a significant degree of association.

Analysis of the Vibrations

Using the method of two of the authors (J. N. A. and H. A. D.) described elsewhere in this journal, an analysis was attempted of the type of vibrations set up during grinding work. The method involves the use of a piezo-electric crystal pickup and an acoustic spectrometer, and its rapidity of recording was particularly useful here because each individual grinding process is of very short duration, in some cases even less than one second. It is to be expected that during each action of grinding the total vibration would build up to a peak and then be reduced again as the worker increases and decreases the pressure, and as the wheel takes up the load on a rough surface and polishes it smooth. A composite picture of the vibration in relation to the duration of the whole grinding 'stroke' could be obtained by using a cinematograph camera technique, but this has not yet been attempted. Instead, single

records were taken when the vibration had reached its maximum as far as could be ascertained. During the grinding of one component it may be turned in all directions, and applied to the wheel for varying periods and at different pressures. The records show a wide variability which is in keeping with this, and it must be emphasized that comparisons can only be made when one factor alone has been allowed to alter. Any comparison of the differences in the vibration obtained from grinding different shapes and sizes of component, or from different sizes of wheel for different parts of the same component, are of limited value only.

In the first case a narrow wheel was being used to grind the angles of a small T-junction piece held in the fingers. The crystal was placed under the left thumb on the upper surface of the casting, facing downwards on to the bench. Normally such a piece is held with tongs in the right hand, and for comparison the crystal was next placed in the palm of the worker's right hand and held firmly against one of the handles of the tongs, all other conditions being kept unchanged. The results appear in Table 6.

This shows that there is a very similar vibration reaching the two hands despite the use of the tongs

TABLE 6

Frequency (cycles per sec.)	Amplitude (microns)	
	Crystal on metal, under L. thumb	Crystal on tongs in R. palm
40.	—	630
50	—	—
64	350	600
80	155	240
100	122	195
125	105	100
160	64	69
200	33	35
250	28	31
320	28	22
400	20	16
500	16	10
640	8	9
800	4	4
1000	2	2
1250	2	2
1600	1	1
2000-10000	trace	trace

in the right. The major frequency is differently placed in the two, and the amplitudes are large. The dimensions of this component were some 2 inches by 1 inch, and $\frac{3}{4}$ inch internal diameter.

The following figures (Table 7) were obtained by placing the crystal at one point on an angle component of larger size, some 4 inches internal diameter and 8 inches overall length. First one end was ground, then the piece was placed flat on the bench and the relatively smooth runner removed from the whole length of the outer surface, and finally the other open end was ground, and this was rough. Though the crystal was fixed in one position on the casting and always under the palm of the left hand, its plane in relation to the grinding wheel surface was altered three times as the workman went through the three manoeuvres.

TABLE 7

Frequency (cycles per second)	Amplitude (microns)		
	End	External runner	End
40	—	—	—
50	—	—	—
64	—	—	—
80	—	—	220
100	—	—	162
125	—	—	96
160	—	—	67
200	—	—	43
250	—	—	31
320	—	—	19
400	—	—	16
500	—	—	8.2
640	—	—	5.9
800	—	—	2.5
1000	—	—	1.4
1250	—	—	1.1
1600	—	0.95	1.4
2000	—	0.62	0.48
2050	—	0.23	0.2
3200	0.16	0.12	0.19
4000–10,000	trace	trace	trace

This series illustrates the variability that is likely to be met in a single set of operations, and that under certain circumstances of grinding a large component the total vibration may be of small quantity, lying at the high-frequency end of the spectrum, having small individual amplitudes, and consisting in fact of the natural 'ring' of the metal only. The conditions are most likely to be fulfilled when the casting is lying in a stable position flat on the bench.

A final set of readings to be considered relates to the grinding of the outer surface runner on a medium-sized casting, again hollow as all these components are, and some 2 inches in internal diameter, 4 inches in overall length, and right-angled in shape. In the first instance the pickup was placed on the inner surface of the angle such that it lay vertically in space with its surface in the same plane as the surface of the wheel itself. In the

second instance the pickup was flat upon the top surface of the casting, its plane being that of the surface of the steel bench (Table 8).

TABLE 8

Frequency (cycles per second)	Amplitude (microns)	
	Crystal pickup vertical	Crystal pickup flat
40	—	255
50	—	—
64	—	100
80	—	80
100	—	51
125	—	43
160	—	53
200	—	32
250	13.5	26.5
320	9.6	14
400	6.1	9.6
500	—	6.4
640	1.95	3.7
800	1.75	2.0
1000	1.5	2.1
1250	1.05	1.9
1600	0.51	0.57
2000–3200	trace	trace
4000–10,000	trace	nil

These figures, besides indicating the wide variability to be expected, show that in any one operation of grinding the vibration takes place in at least two dimensions, for the crystal pickup only responds effectively to vibration in a plane at right angles to its flat surface. In the case just quoted the conditions in the two halves of the experiment were kept identical, only the plane of the pickup being changed. When in a vertical position the total vibration is small, nothing is encountered below 250 cycles, and even the greatest amplitude is small. When in the horizontal position the frequencies extend throughout the spectrum, and at the lower frequencies the amplitudes are large. This indicates that the vibration taking place in a direction at right angles to the surface of the wheel is slight, but that in a vertical direction, i.e. tangential to the wheel surface, it is large. Little assessment of the quantity reaching the fingers can be made, because they are wrapped round such a casting in all directions and can therefore absorb vibration in various planes at once.

In all these experiments means have been taken of either three or six readings, but in any one experiment the variation from moment to moment was surprisingly small. Further records were taken to consider other aspects of the grinding, but they serve to emphasize the variability of the vibrations which is in keeping with the many variable experimental conditions met. A series was contemplated to compare the effects of grinding a given component on wheels of different sizes, but this would have had little practical application, as it is rarely seen that one particular type is ground on both the

large and the small wheels. In general terms little difference between the effects of the various types of wheel could be detected, though detailed comparisons are inadmissible for the reasons already given.

Discussion

An assessment of the degree of disability in this condition is notoriously difficult. In the paper by Telford, McCann and MacCormack (1945), the cases exhibited an identical syndrome from a different type of work, but were not a true cross-section of all the workers on the job, for they were a selected group made up of those presenting with definite symptoms and therefore above the average in severity. The disability was described there as 'severe', and the uselessness of the hand during the attacks was emphasized. But it is only the cutaneous sensibility that is lost, not the muscular power. Grinding requires muscular power but not much delicacy of touch. Therefore, what is disability for a former textile worker about to return to his old job may not constitute disability for a grinder. Similarly, an outdoor worker may have more cause for complaint than an indoor one, because he is liable to more frequent attacks from the cold. In the present series there has been nothing to suggest that the more serious lesions, such as trophic skin changes or even gangrene, are to be expected.

It is worth noting that in our series the men were mostly contented and in many cases did the work from choice; they had seldom been directed from other occupations. This may have considerable bearing on their lack of concern for their symptoms. In other parts of the country where Raynaud's phenomenon occurs also from working conditions, more disability is claimed where there has been unwelcome direction of labour, or where men have suddenly been declared redundant after having had a lucrative job.

Cases have been coming to the fore in the last two or three years even though grinding processes

such as this have been in use for many years. Whether this is a function of a tendency in the general population, or of the specific effect of increased pressure of work and longer hours combined with more medical supervision in factories, or whether it is from all these causes coupled by some such factor as dietary deficiencies in wartime, it is not yet possible to say.

At present there appears to be no possible prophylactic measure that can be applied. If all the work could be done by machinery the problem would be solved, but the skill and speed required and the complexity of the manipulations make this scarcely possible. Hand grinding will always produce vibration, and the best that can be hoped for is some method in which the man touches the metal as little as possible, or some suitable absorbent material to cover his fingers without hindering the work unduly.

Summary

Thirty-seven workers from a grinding shop were examined, and thirty-two had Raynaud's phenomenon in cold weather. The type of work and the grinding equipment is described. Clinical findings suggested that the lesions were mostly bilateral, came on at an average of 21 months from the time of starting the work, and caused relatively little disability; the exact distribution of the lesions was noted. There is some evidence to suggest that the processes of grinding with the larger wheels cause a more widespread lesion than others; also that the disturbance becomes more extensive the longer that work with a large wheel goes on. Experimental work on the quality of the vibrations set up shows the order of the frequencies and amplitudes concerned, the considerable variability, and the fact that vibration is taking place in several directions at once.

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