Rheumatism in Foundry Workers

J. S. LAWRENCE, M. K. MOLYNEUX, and IANTHE DINGWALL-FORDYCE

From the Arthritis and Rheumatism Council Field Unit and the Nuffield Department of Occupational Health, University of Manchester

In order to investigate loss of work from rheumatic diseases in the metal trades, employees in 10 foundries were questioned.

Of 325 foundry workers aged 35 to 74 years, who had worked for at least 10 years on the foundry floor, 299 were examined clinically and radiologically for evidence of rheumatic disease. Radiographs of the hands, knees, and dorsal and lumbar spine were taken as a routine, and the pelvis was included in those aged 45 and over. A comparison was made with a control series of radiographs, from men, matched for age, in a random population sample examined earlier in the town of Leigh.

Rheumatic complaints in general were less frequent in the foundry workers than in the random sample, and the foundry workers less often gave a history of prolonged incapacity (three months or more) due to this cause.

Radiological evidence of disc degeneration in the lumbar spine, however, was more frequent in the foundry workers than in the controls and was of greater severity. Further, the foundry workers more commonly had symptoms and signs of lumbar disc prolapse. On the other hand, the controls had more osteo-arthritis of the hips and knees and lost more work from pain at these sites. This was associated with a difference of body habitus, obesity being less frequent in the foundry workers.

Foundry workers directly exposed to hot conditions did not have less back or leg pain than those not so exposed despite a greater prevalence of disc degeneration.

Measurements of air temperature, humidity, and radiant heat were made in a foundry while pouring was in progress. The air temperature rose from 18°C. to 26°C. and the humidity ranged from 70% to 54%. The mean intensity of radiation incident on the clothed surface of a foundry worker was 0.12 watt/cm.². This was compared with conditions during therapeutic exposure to radiant heat. The radiant heat under conditions of 'heat therapy' varied between 0.16 and 0.37 watt/cm.². The possible influence of radiant heat on the prevalence of rheumatic complaints is discussed.

Statistics produced by the Ministry of Pensions and National Insurance in the United Kingdom indicate that, if unskilled workers are excluded, the greatest number of claims for incapacity due to arthritis and rheumatism (excluding rheumatic fever) are made by persons engaged in metal, engineering, and allied trades. In June 1955, for example, claims were received from 4,080 workers in these trades compared with 5,760 unskilled workers and 3,400 miners. The number of workers at risk is not accurately known but there can be little doubt that this reflects in part the frequency of such occupations in the community. In the absence of reliable information on the size and age distribution of this occupational group it was decided to carry out a detailed survey. As foundry workers form a well defined sub-group and lose work more

frequently than any other metal workers, this survey was limited to foundry workers. Statistics produced by the Amalgamated Union of Foundry Workers show that rheumatism is an important cause of incapacity in their members, coming second only to respiratory disease and influenza.

Little has appeared in the medical literature on this subject but Vernon (1921) found that puddlers of wrought iron lost an excessive amount of work from rheumatism and he attributed this to periods of heavy work under high temperature conditions followed by sitting about in draughts. Steel melters, who are also engaged in heavy intermittent work, lost more than the average amount of work from rheumatism.

Method of Survey

Foundries, whether attached to large engineering

Received for publication April 10, 1965.

shops or acting as independent units, are usually small and employ on an average some 30 men. It was therefore felt that a survey of a single large foundry would not give a representative sample. It was decided to include one foundry with more than 200 employees and to distribute the rest of the survey over a number of smaller foundries* employing 20 to 100 men.

The survey was limited to men aged 35 and over, who had worked for at least 10 years on the foundry floor and were so working at the time of the survey or were temporarily away from their work because of sickness or accident. No information was available on foundry men who had left the industry because of illness but these were considered by the management to be few. Trades included were moulders, coremakers, dressers and arc welders, pattern makers, and general labourers.

After a history had been taken of past illnesses and present symptoms, a clinical examination of the musculo-skeletal system was carried out on all men having the above qualifications. Radiographs were taken of the hands, knees, and dorsal and lumbar spine as a routine and of the pelvis in those aged 45 and over. Only a lateral view was taken of the spine and an anterior-posterior view of the other parts. A comparison was made with a series of radiographs from the Leigh random population sample (Lawrence and Bennett, 1960) matched by age with the foundry workers. As there were insufficient men aged 35 to 44 in the Leigh sample, 26 men in this age group were obtained from an area sample in Wensleydale (Bremner, 1961) to complete the

controls. The radiographs of the foundry workers and controls were mixed randomly and read 'blind'. The changes found were graded in accordance with the *Atlas of Standard Radiographs of Arthritis* (1963).

The sample of foundry workers totalled 325, of whom 299 were examined, a completion rate of 92%. The 8% who were not examined were mainly in the 45-54 age group (Table I).

TABLE I
COMPLETENESS OF SURVEY

Age	Total in Sample	Not Available or Refused Examination	Examined	Completion Rate (%)
35-44	126	6	120	95
45-54	119	13	106	89
55-64	69	2	67	97
65+	6	0	6	100
Not stated	5	5	—	—
Total	325	26	299	92

Results

Rheumatic Symptoms Of the 299 foundry workers who were examined, 188 (63%) gave a history of rheumatic complaints (Table II). The expected number, as determined by correction of the Leigh random males to the age distribution of the foundry workers, is 219 ($\chi^2 = 4.3$, $P < 0.05$). Of the 188 foundry workers with symptoms, 103 had lost work from rheumatism and 26 had lost three months or more compared with expected rates of 104 and 43. The difference between the number of foundry workers and controls who lost three months or more is significant ($\chi^2 = 6.3$, $P < 0.02$). The number of foundry workers with symptoms at the time of the survey was 80, and two were actually off work from rheumatism, compared with an expected 107 with complaints ($\chi^2 = 6.5$, $P < 0.01$) and five off work. None had been off for three months or

*The following foundries took part in the survey: J. Needham & Sons, Stockport, Cheshire; J. R. Clayton, Stockport, Cheshire; Storey Foundry Co., Reddish, Cheshire; E. Pass & Co., Denton, Lancashire; R. Broadbent & Sons, Stalybridge, Cheshire; Ferranti Ltd., Hollinwood, Lancashire; J. Hodgkinson (Salford) Ltd., Salford, Lancashire; W. H. Bailey & Co., Patricroft, Lancashire; Warrington Light Castings Co., Warrington, Lancashire; Wyman's Foundry, Warrington, Lancashire.

TABLE II
RHEUMATIC COMPLAINTS IN FOUNDRY WORKERS

Age	Total	Since Birth					
		Total with Complaints	Off Work		Total with Complaints	Off Work	
			1 Week +	3 Months +		1 Week +	3 Months +
35-44	120	74	35	10	30	1	—
45-54	106	66	38	9	30	1	—
55-64	67	47	29	7	20	—	—
65+	6	1	1	—	—	—	—
Total	299	188*	103	26*	80†	2	—
Expected		219	104	43	107	5	3

* $P < 0.05$. † $P < 0.01$.

TABLE III
SITE OF PAIN IN FOUNDRY WORKERS AND CONTROLS

	Total		Off Work 1 Week +		Off Work 3 Months +	
	Foundry	Expected	Foundry	Expected	Foundry	Expected
<i>Segmental</i>						
C1-4	12	18	7	13	3	3.7
C5-D2	40†	60	26	27	4	3.3
D3-11	46	40	29	20	6	4.0
D12-L2	90	89	59	51	15	18.7
L3-4	12‡	34	7†	23	0†	8.6
L5-S2	25	22	16	14	5	6.7
<i>Local</i>						
Fingers	10	17	5	10	2	3.7
Thumbs	2*	8	2	6	0	3.0
Wrists	16	13	9	10	3	3.7
Elbows	25	18	14	13	4	0
Shoulders	30	43	19	18	2	0.1
Hips	5*	14	1*	8	0	1.4
Knees	31‡	57	15‡	35	4*	12.9
Ankles	5†	18	5	10	3	3.0
Tarsi	3‡	20	2*	8	1	5.0
Toes	5	6	4	5	2	4.3
Multiple Undefined	4*	11	3	8	1	4.2

*P < 0.05.

†P < 0.01.

‡P < 0.001.

more with rheumatic troubles at the time of the survey though this would be expected in three. Complaints were mainly of pain in the low back and groins in the D12-L2 segmental distribution (Table III). In no sites, apart from the wrists and elbows and in the D3-11 and L5-S2 distribution (sciatic), was pain more frequent in the foundry workers, and here the differences were not significant. There was significantly less pain at a number of sites in the foundry workers, notably in the knees, ankles, and tarsi (P < 0.001). Segmental pain in the legs and arms in the L3-4 and C5-D2 distribution was also significantly less frequent in the foundry workers. Loss of work due to pain in the hips, knees, and tarsi and in the L3-4 segmental distribution was less frequent in the foundry workers.

Radiological Findings In the lumbar spine the foundry workers had more disc degeneration of grades 2, 3, and 4 and less of grade 0 than the controls (Table IV). Grade 3-4 disc degeneration was encountered in 18% of the foundry workers and in 11% of the controls and was more frequent at all ages in the foundry workers ($\chi^2 = 4.5$, P $\approx$ 0.04).

The number of discs affected was similar in the foundry workers and controls, 25% and 27% respectively having involvement of four or more discs. The control group included 79 coal-miners who are known to exhibit severe disc degeneration (Kellgren and Lawrence, 1952). When these were removed the prevalence of grade 3-4 disc degeneration fell slightly, the mean equivalent rate, after correction for age distribution, being 10% compared with 12% in the total control group and 18% in the foundry workers. The difference between the foundry workers and non-miners, taking age into account, is highly significant (P < 0.001).

Of the foundry workers, the moulders and general labourers showed the greatest frequency of disc degeneration, 20% and 22% respectively having grade 3-4 disc degeneration. Grade 4 disc degeneration, however, was found only in moulders. The high prevalence and severity of disc degeneration in moulders cannot be explained by age distribution since half of them were in the youngest age group, but the labourers had less than a third in this age group and would thus be expected to have a higher prevalence. There was no difference between those

Rheumatism in Foundry Workers

45

TABLE IV
LUMBAR DISC DEGENERATION

Age	Total X-rayed	Grade of Lumbar Disc Degeneration							No. of Individuals with Grade 1-4 Degeneration in Four or more Discs	
		0	1	2	3	4	2-4 (%)	3-4 (%)	Actual	%
Foundry Workers										
35-44	117	27	17	62	9	2	62	9	10	9
45-54	102	7	11	63	19	2	82	21	32	31
55-64	65	4	2	42	16	1	89	26	27	41
65+	6	0	0	3	3	0	100	50	3	50
Total	290	38	30	170	47	5	76	18	72	25
Mean equivalent rate							18%*		25	
Controls										
35-44	114	48	12	48	5	1	47	5	8	7
45-54	103	12	12	66	13	—	77	13	40	39
55-64	64	7	6	39	11	1	80	19	27	42
65+	6	—	—	4	2	—	100	33	3	50
Total	287	67	30	157	31	2	66	11	78	27
Mean equivalent rate							12%			
Controls without miners and heavy industry										
35-44	75	34	8	31	1	1	44	3	4	5
45-54	75	8	8	49	10	0	79	13	29	39
55-64	54	7	4	34	8	1	80	17	26	48
65+	4	0	0	3	1	0	100	25	2	40
Total	208	49	20	117	20	2	67	11	61	29
Mean equivalent rate							10%		25	

*P < 0.001.

workers in the large foundry and those in the smaller foundries as regards frequency and severity of lumbar disc degeneration.

In the dorsal spine disc degeneration grade 2-4 was found in 70% of the 289 foundry workers who

had radiographs of this region (Table V). Control radiographs of the dorsal spine were available in only 114, of whom 81% had grade 2-4 disc degeneration. These were not selected in any way but represent the second half of the Leigh survey. After

TABLE V
DORSAL DISC DEGENERATION

Age	Total X-rayed	Grade of Dorsal Disc Degeneration						No. of Individuals with Grade 1-4 Degeneration in Eight or more Discs	
		0	1	2	3	4	2-4 (%)	Actual	%
Foundry Workers									
35-44	117	42	3	66	6	0	61	0	0
45-54	101	21	5	59	16	0	74	2	2
55-64	65	8	1	29	26	1	86	3	5
65+	6	0	0	3	3	0	100	1	17
Total	289	71	9	157	51	1	70	6	2
Equivalent average rate							80%	6	
Controls									
35-44	44	11	3	25	5	0	68	1	2
45-54	49	4	1	33	11	0	90	4	8
55-64	15	1	1	9	4	0	87	1	7
65+	6	0	1	2	2	1	83	1	17
Total	114	16	6	69	22	1	81	7	6
Equivalent average rate							82%	8	

TABLE VIA
RADIOLOGICAL OSTEO-ARTHROSIS OF THE HANDS

Age	Foundry Workers							Controls						
	Total X-rayed	Grade						Total X-rayed	Grade					
		0	1	2	3	4	2-4		0	1	2	3	4	2-4
Distal Interphalangeal Joints														
35-44	120	106	9	4	1	0		119*	105	6	7	1	0	
45-54	106	76	8	19	3	0		106	61	11	33	1	0	
55-64	67	26	17	19	5	0		67	27	11	24	5	0	
65+	6	2	1	3	0	0		65+	0	1	3	2	0	
Total	299	210	35	45	9	0	18%*	298	193	29	67	9	0	26%
Proximal Interphalangeal Joints														
35-44	120	116	0	4	0	0		119*	116	1	2	0	0	
45-54	106	94	5	7	0	0		106	96	7	3	0	0	
55-64	67	50	5	11	1	0		67	51	7	8	1	0	
65+	6	4	1	1	0	0		6	3	1	2	0	0	
Total	299	264	11	23	1	0	8%*	298	266	16	15	1	0	5%
Metacarpophalangeal Joints														
35-44	120	112	3	5	0	0		119*	105	9	5	0	0	
45-54	106	83	10	11	2	0		106	72	18	16	0	0	
55-64	67	45	5	13	4	0		67	40	9	16	2	0	
65+	6	3	1	0	2	0		6	3	2	0	1	0	
Total	299	243	19	29	8	0	12%	298	220	38	37	3	0	13%
Carpometacarpal and Intracarpal Joints														
35-44	120	113	6	1	0	0		119*	106	10	3	0	0	
45-54	106	88	7	10	1	0		106	78	13	14	1	0	
55-64	67	48	9	5	5	0		67	43	11	11	1	1	
65+	6	1	2	2	1	0		6	4	0	1	1	0	
Total	299	250	24	18	7	0	8%	298	231	34	29	3	1	11%

*P < 0.05.

TABLE VIB
RADIOLOGICAL OSTEO-ARTHROSIS OF THE SPINE AND LOWER LIMBS

Age	Foundry Workers							Controls						
	Total X-rayed	Grade						Total X-rayed	Grade					
		0	1	2	3	4	2-4		0	1	2	3	4	2-4
Lumbar Spine														
35-44	117	85	23	8	1	0		114	61	33	19	1	0	
45-54	102	64	25	11	2	0		103	50	36	15	2	0	
55-64	65	39	15	8	3	0		64	29	20	12	3	0	
65+	6	3	2	0	1	0		6	2	1	3	0	0	
Total	290	191	65	27	7	0	12%*	287	142	90	49	6	0	19%
Hips														
45-54	100	82	11	6	1	0	7%*	28	20	3	5	0	0	18%
55-64	64	43	13	7	1	0	13%*	64	33	11	15	5	0	31%
65+	6	4	0	2	0	0		6	3	2	1	0	0	
Total	170	129	24	15	2	0		98	56	16	21	5	0	
Sacro-iliac Joint														
45-54	98	93	3	2	0	0	2%	28	26	1	0	1	0	4%
55-64	64	52	8	4	0	0	6%	64	53	8	2	1	0	5%
65+	6	4	1	1	0	0		6	5	1	0	0	0	
Total	178	157	14	7	0	0		98	84	10	2	2	0	
Knees														
35-44	118	100	12	6	0	0		114	95	10	9	0	0	
45-54	103	73	17	12	1	0		101	60	19	19	3	0	
55-64	67	42	11	11	3	0		67	19	20	22	4	2	
65+	6	2	1	3	0	0		5	2	0	3	0	0	
Total	294	217	41	32	4	0	12%*	287	176	49	53	7	2	22%

*P < 0.01.

TABLE VII
DISC PROLAPSE IN FOUNDRY WORKERS

Age	Total	Grade of Disc Prolapse											
		Cervical						Lumbar					
		Actual				Expected		Actual				Expected	
		0	1	2	3	1-3	2-3	0	1	2	3	1-3	2-3
35-44	120		1	1	0			6	3	2			
45-54	106				0			7	5	1			
55-64	67			1	0			3	5	2			
65+	6				0					0			
Total	299		1	2	0	3.11%	1.41%	16	13	5		9.44%*	5.21%*

*P < 0.001.

correction for age distribution the proportions were 80% in the foundry workers and 82% in the controls. Changes were present in eight or more discs in 6% of the foundry workers and 8% of the controls after age-correction. It may be concluded that there is no increase of degenerative disc change in the dorsal spine in foundry workers.

Osteo-Arthrosis The foundry workers had significantly less osteo-arthrosis than the controls in the apophyseal joints of the lumbar spine and in the distal interphalangeal joints of the fingers but particularly in the knees and hips ($P < 0.01$). In none of the joints was there significantly more osteo-arthrosis in the foundry workers (Table VI). The lowest prevalence of osteo-arthrosis of the hips was found in the miscellaneous group of foundry workers, of whom only 3% had definite radiological changes, and of osteo-arthrosis of the knees in the dressers, only 3% of whom were affected.

Rheumatoid Arthritis Only two foundry workers were diagnosed as having rheumatoid arthritis on clinical examination, and in both cases it was of minimal severity. The expected number in a sample of this age distribution, as calculated from the random population samples in the North of England, would be nine (Lawrence, 1961). Because of the small numbers there was no significant difference between foundry workers and the general population. Radiological evidence of erosive arthritis was found in 26 (9%) of the foundry workers and in 21 (7%) of the controls. In all but one in each group it was of minimal severity. Persons with severe rheumatoid arthritis are unable to undertake heavy manual work, which may well account for the lower prevalence of this disease in the foundry workers.

Other Diseases A diagnosis of disc prolapse was made in 36 of the foundry workers. Of those

with disc prolapse, 33 had lumbar prolapse alone, two cervical alone and one both. Of those with lumbar disc prolapse, 16 had it at grade 1 severity, and 18 at grade 2-3 (Table VII). The numbers expected to have lumbar disc prolapse judged from the population sample in Leigh would be five grade 1 and five grade 2-3. There was thus more than three times the expected amount of lumbar disc prolapse in the foundry workers, a very significant increase. The increased prevalence of lumbar disc prolapse was not limited to any one occupation in the foundry, those affected being evenly distributed among the occupational groups. Cervical disc prolapse was found to have approximately the same prevalence as in the random sample.

Spondylitis was diagnosed on clinical examination and confirmed by radiography in two foundry workers. This prevalence of 0.7% is not significantly greater than the prevalence of 0.4% noted in men from random population surveys in the North of England (Lawrence, 1963). Radiological evidence of sacro-iliitis was noted in 4% of the foundry workers and in 4% of the controls. Except in the two foundry workers with spondylitis, it was of minimal severity. Other connective tissue disorders encountered were capsulitis or synovitis in eight foundry workers, Dupuytren's contracture in two, bursitis in three, and gout in three.

Relationship of Symptoms and Loss of Work to Radiological Changes

Comparison of Foundry Workers and Controls A relationship between the radiological changes of osteo-arthrosis in the hips, knees, and joints of the hands and pain in the region of these joints has been demonstrated in random population samples (Bier, Bremner, and Lawrence, 1965). Disc degeneration in the lumbar spine has similarly been shown to be related to back-sciatic pain (Lawrence, de Graff, and Laine, 1963). No relationship was found in those

studies between dorsal disc degeneration and dorsal pain or between osteo-arthritis of the dorsal or lumbar apophyseal joints and symptoms. In Table VIII the frequency of pain and incapacity at various sites in the foundry workers is compared with the

expected frequency determined from the Leigh random sample after adjustment for age and frequency of radiological change. Despite a higher prevalence of lumbar disc degeneration in the foundry workers there were fewer symptoms than

TABLE VIII
SYMPTOMS AND INCAPACITY FROM PAIN AT CERTAIN SITES IN RELATION TO
AMOUNT OF DISC DEGENERATION OR OSTEO-ARTHRITIS

Site of X-ray Changes	Site of Symptoms	Number with Pain		Number off Work			
		Expected	Observed	1 Week +		3 Months +	
				Expected	Observed	Expected	Observed
Disc degeneration lumbar grade 3-4	D12-L2	135.5	90†	76.5	59	28.5	15
	L3-4	51.0	12†	34.5	7†	13.5	0*
	L5-S2	33.0	25	21.0	16	10.5	5*
Osteo-arthritis grade 2-4							
Hips	Hips	7.0	5	4.0	1	0.5	0
Knees	Knees	31.1	31	19.1	15	7.1	4
First carpometacarpal joint	Thumbs	5.8	2	4.4	2	2.2	0
Wrists	Wrists	11.0	16	8.6	9	3.4	3
Distal interphalangeal joint	Fingers	11.8	7	3.0	1	2.0	1
Proximal interphalangeal joint	Fingers	40.0	11†	8.0	1*	6.4	1
Metacarpophalangeal joint	Fingers	19.4	10*	4.6	2	3.7	1

Expected numbers are those which would have occurred had the ratio of radiological changes and symptoms been the same among the foundry workers as it was in the Leigh population sample.

N.B.—This table is based on the total workers examined clinically. Of the foundry workers clinically examined, 97% had a radiograph of the lumbar spine; of the Leigh controls, 96% were X-rayed.

*P < 0.05 > 0.01.

†P < 0.001.

TABLE IX
SYMPTOMS AND ABSENCE DUE TO BACK AND LEG PAIN IN WORKERS EXPOSED TO
RADIANT HEAT IN THE FOUNDRY

Conditions of Work	No. of Workers	Segmental Distribution of Pain	No. with Pain		No. off Work			
			Expected	Observed	1 Week +		3 Months +	
					Expected	Observed	Expected	Observed
Heat	140	D12-L2	40.6	41	22.5	29	10.6	9
No heat	61		19.2	15	10.7	8	4.9	1
Mixed	89		27.9	28	15.8	14	7.5	2
Total	290		87.7	84	49.0	51	23.0	12*
Heat	140	L3-4	15.4	7*	10.2	2*	5.1	0*
No heat	61		6.7	2	4.8	0	2.2	0
Mixed	89		11.0	3*	7.2	2	3.5	0
Total	290		33.1	12	22.2	4	10.8	0
Heat	140	L5-S2	9.7	13	6.4	8	3.5	4
No heat	61		4.3	4	2.8	0	1.3	0
Mixed	89		7.6	7	4.7	5	2.5	0
Total	290		21.6	24	13.9	13	7.3	4

Heat = moulders, furnace hands, and welders.

No heat = core and pattern makers and dressers.

Mixed = other.

*Based on the total no. of workers who had radiographs of the lumbar spine.

expected and less incapacity from pain in the D12-L2, L3-4, and L5-S2 segmental distribution. In the case of the D12-L2, L3-4 pain this difference was highly significant ($P < 0.001$). Loss of work from hip pain occurred in only one foundry worker. In relation to the amount of osteo-arthritis, there was significantly less pain in the proximal interphalangeal ($P < 0.001$) and metacarpophalangeal ($P \approx 0.05$) joints in the foundry workers, and in the hips, first carpometacarpal, and distal interphalangeal joints it was also less, though not significantly so. Incapacity was less from pain at all sites radiographed except the wrists but was significantly less ($P \approx 0.05$) only in the proximal interphalangeal joints of the fingers. The miners did not have more than the expected frequency of symptoms in relation to the degree of radiological change.

Comparison of Different Types of Foundry Workers Since foundry workers are exposed to radiant heat more than other workers and since the pain threshold is known to be influenced by tissue temperature, it is important to know whether a reduction in symptoms is related to the degree of exposure to radiation. The foundry workers have therefore been divided into three groups (a) the moulders, furnace hands, and welders who are exposed to considerable radiation, (b) the core and pattern makers and dressers who work at some distance from the furnace and the pouring ladles, and (c) a mixed group of general labourers whose exposure varies.

In Table IX the prevalence of back and leg pain

and resulting loss of work in those foundry workers exposed and not exposed to heat is shown and is compared with the expected prevalence assessed from the population of Leigh. The relative amounts of lumbar disc degeneration are not taken into account in this table. It will be observed that those workers who were exposed to heat showed about the same reduction in pain in the L3-4 distribution and in loss of work from this cause as those not exposed to heat, and the expected amount of pain in the other sites. The radiological changes of disc degeneration in the lumbar spine (Table X), however, were significantly greater at grades 2-4 in those working in heat ($P < 0.001$) despite the fact that these workers were younger than those not so exposed and would be expected to have less disc degeneration. Thus it would be expected that the 'hot' workers would have much more pain.

Discussion

One of the most striking features in this survey was the low prevalence of rheumatic complaints in the foundry workers, particularly those complaints associated with prolonged incapacity.

This contrasts with data from the Ministry of Pensions and National Insurance and with the findings of Vernon (1921) already mentioned. The large number of claims on the Ministry of Pensions and National Insurance may well reflect a very considerable number at risk in the population but it indicates the need for surveys of other groups of metal workers. Vernon's data were derived from a comparison between certain groups of workers within the foundries, and no comparison was made with the general population.

The low complaint rate which we have encountered in the foundry workers cannot be attributed to poor memory for past painful episodes since there were fewer complaints present at the time of the survey. The deficit of prolonged incapacity was related mainly to knee, thigh, and tarsal pain. The low frequency of thigh and knee pain may be explained in part by the diminished frequency of osteo-arthritis in the hips and knees in the foundry workers. It would, however, be expected that some thigh pain would result from the lumbar disc degeneration, which was more severe in the foundry workers. The third lumbar disc was more often affected than any other in the foundry workers, and the fourth was also commonly involved. Pain referred from these segments of the spine is felt in front of the thighs (Kellgren, 1940). Thus it would appear that some other factor is responsible. A possible explanation is that the pain threshold is raised as a result of the warm dry

TABLE X

AGE DISTRIBUTION AND GRADES OF DISC DEGENERATION
IN FOUNDRY WORKERS EXPOSED AND NOT EXPOSED
TO HEAT

	Conditions of Work			
	Heat		No Heat	
Age of those X-rayed	(%)		(%)	
35-44	67	48	28	46
45-54	46	33	15	26
55-64	26	19	18	29
65+	1	—	—	—
Total	140	—	61	—
Grades of disc degeneration				
Total	140	—	61	—
0	10	7.1	15	24.6
1	15	10.7	11	18.0
2	87	62.1	30	49.2
3	23	16.4	5	8.2
4	5	3.6	0	—
2-4	115	82	35	57*

* $P < 0.001$

FIG. 1. Thermal environment in the iron foundry. Location: (1) Ladle driver 10 ft., 30°; (2) mould making; (3) mould pouring (a) 20 ft., back pot, (b) 10 ft., front pot, (c) 10 ft., front pot; (4) full hot moulds; (5) tapping 20 ft., 60°; (6) mould pouring front 15 ft.; (7) mould pouring front 20 ft., 30°; (8) mould pouring side 15 ft., 5°; (9) mould pouring front 12 ft.; (10) mould pouring front 20°, 30°; (11) after pouring; (12) furnace.

atmosphere in the foundry, or from exposure to radiant heat from the molten metal. A relationship between pain threshold and tissue temperature is known to exist, and it has been found that the symptoms of both disc degeneration and osteoarthrosis are less frequent and disabling in miners working in warm dry seams than in those in cold wet seams (Kellgren, McGowan, and Hughes, 1948; Lawrence, 1955).

Because of a possible association between exposure to radiant heat and the low prevalence of musculo-skeletal pain in these foundry workers, it was decided to study the conditions of work, particularly with reference to air temperature, radiant heat, and humidity.

Measurements were made in a typical small foundry during the pouring of molten iron (1,500°C.). The intensity of radiation incident on

TABLE XI											
THERMAL ENVIRONMENT IN 11 POSITIONS											
Location	Position of Instruments in Relation to Hot Surface		Temperature						Relative Humidity (%)	Vel. Air (m./min.)	Thermopile, Radiant Heat (watts/cm. ²)
			Mean Radiant Temp.		Dry Bulb		Wet Bulb				
	Distance (m.)	Angle (°)	°F.	°C.	°F.	°C.	°F.	°C.			
1 Ladle driver	(a) 3	30									(a) 0.05
	(b) 3	30									(b) 0.05
2 Mould making	—	—	300	149	65	18	59	15	70	4.5	—
3 Mould pouring	(a) 6	Back	345	174	73	23	64	18	63	22.9	(a) 0.05
	(b) 3	Front									(b) 0.30
	(c) 3	Front									(c) 0.16
4 Full hot mould	Centre (1.5 m. above)	—	379	193	69	21	61	16	63	54.9	—
5 Tapping	6	60									0.07
6 Mould pouring	5	Front									0.10
7 Mould pouring	6	30									0.14
8 Mould pouring	5	5									0.06
9 Mould pouring	4	Front									0.18
10 Mould pouring	6	30									0.15
11 After pouring	Centre (1.5 m. above)	—	330	166	79	26	67	19	54	9.0	—
										Mean radiant heat energy	0.12

Technique of temperature and humidity measurements: (1) radiant heat, measured by radiation thermopile; (2) mean radiant temperature of surroundings, measured by globe thermometer; (3) air temperature and relative humidity, measured by dry and wet bulbs of whirling hygrometer.

the workers was determined with a radiation thermopile. For comparative purposes, measurements of the intensity of radiation were made with the same instrument during radiant heat treatment in a physiotherapy department.

Thermal measurements, made in 11 places in the foundry (Fig. 1), indicate the variation of working conditions (Table XI).

The mean radiant temperature of the surroundings measured by the globe thermometer in locations 2, 3, 4, and 11 varied between 149°C. and 193°C. These readings were taken during the short period of intense radiant heat directed from the surface of the molten metal. During these operations there was a relatively small increase in air temperature and a reduction of humidity. The air movement throughout the foundry was low, varying between 4.5 and 54.9 metres/minute.

In the foundry, the radiant heat incident upon the body of the lightly clothed workman varied between 0.05 and 0.30 watt/cm.², with a mean value of 0.12 watt/cm.², in eight locations. The exposure is intermittent and transitory, these conditions being experienced for approximately two hours on each of two days per week.

The results obtained in the foundry using the radiation thermopile have been compared with the radiant heat experienced during heat therapy (Table XII).

TABLE XII
THERAPEUTIC RADIANT HEAT
(‘Radiant’ and Infrared)

Method	Power of Heat Source (W)	Distance (cm.)	Thermopile, Radiant Heat (watt/cm. ²)
Radiant heat	1000	76	0.16
Radiant heat	1000	58	0.37
Infrared	600	76	0.22
Infrared	600	58	0.30
Infrared	600	58	0.31

In comparison, a patient undergoing ‘radiant heat’ therapy can be exposed to between 0.16 and 0.37 watt/cm.², whereas the exposure during ‘infrared’ therapy is between 0.22 and 0.31 watt/cm.². In normal circumstances heat therapy would normally be given for three periods of 30 minutes each week for two months. Relief of pain occurs in some 80% of rheumatic sufferers during such therapeutic exposures and has a mean duration of 10 hours following exposure to radiant heat (Lawrence and Sladden, 1955). In some patients relief may last up to 48 hours, and it seems reasonable to suppose that in those with mild rheumatic disorders the complaint rate and capacity for work might be influenced by

the amount of radiation received in the foundry.

The increased prevalence of disc degeneration in the foundry workers is not unexpected. An association between heavy lifting and disc degeneration has already been demonstrated in other occupations (Lawrence, 1955). Although mechanical lifting has now replaced much of the heavy manual work associated with foundries, the earlier years must inevitably have produced permanent changes in the discs. The greater prevalence of disc degeneration in those foundry workers directly exposed to hot conditions may be due to the heavier nature of their work, but a higher pain threshold might also play a part. The relatively high prevalence of symptoms due to lumbar disc prolapse may be explained by the fact that pain in these cases is due to root pressure which may not be influenced by tissue temperature to the same extent as referred pain. Moreover, the initial symptoms of disc degeneration are more likely to go unheeded by a worker in a warm environment until rupture of the annulus ensues.

The lower prevalence of osteo-arthritis in the weight-bearing joints, such as the hips, knees, and lumbar spine, suggests an influence of body habitus. Obesity has been shown to be associated with a greater prevalence of osteo-arthritis in these joints and was in fact less frequent in the foundry workers. Only 15% of the foundry workers were graded as having even minimal obesity compared with an expected rate of 31% as judged from the Leigh random sample in this age distribution. An unexplained association between obesity and osteo-arthritis of the distal interphalangeal joints was noted in the Leigh random sample and is reflected in a low frequency of osteo-arthritis in these joints in foundry workers (Kellgren and Lawrence, 1958). The absence of obesity in foundry workers is presumably associated with the strenuous nature of the work and the relatively warm working conditions.

We wish to express our thanks to members of the North Western Ironfounders Employers’ Association and the National Light Castings Ironfounders’ Federation, Glasgow and to officials and members of the Amalgamated Union of Foundry Workers and the Transport and General Workers Union for their willing co-operation in this survey.

We are indebted to Professor R. E. Lane and Dr. W. R. Lee for much advice, helpful comments, and criticism.

REFERENCES

- Atlas of Standard Radiographs of Arthritis* (1963). Blackwell, Oxford.
- Bier, J., Bremner, J. M., and Lawrence, J. S. (1965). In press.
- Bremner, J. M. (1961). *Ann. rheum. Dis.*, 20, 149.
- Kellgren, J. H. (1940). *Clin. Sci.*, 4, 303.
- , McGowan, A. J., and Hughes, E. S. R. (1948). *Ibid.*, 7, 13.

- Kellgren, J. H., and Lawrence, J. S. (1952). *Brit. J. industr. Med.*, **9**, 197.
- and — (1958). *Ann. rheum. Dis.*, **17**, 388.
- Lawrence, J. S. (1955). *Brit. J. industr. Med.*, **12**, 249.
- (1961). *Ann. rheum. Dis.*, **20**, 11.
- (1963). *Brit. J. clin. Pract.*, **17**, 699.
- and Bennett, P. H. (1960). *Ann. rheum. Dis.*, **19**, 20.
- , de Graff, R., and Laine, V. A. I. (1963). In *The Epidemiology of Chronic Rheumatism*. Ed. by M. R. Jeffrey and J. Ball under the direction of J. H. Kellgren, Vol. 2, p. 98. Blackwell, Oxford.
- and Sladden, R. J. (1955). *Ann. phys. Med.*, **2**, 282.
- Vernon, H. M. (1921). *J. industr. Hyg.*, **3**, 93.