CHAMBER OF MINES OF SOUTH AFRICA

RESEARCH ORGANIZATION

REPORT

ON

A GUIDE TO THE MEASUREMENT AND ASSESSMENT OF HEAT STRESS IN GOLD MINES

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C.O.M. REFERENCE: PROJECT NO. GY6H21
RESEARCH REPORT NO. 14/78

APRIL, 1978

REFERENCE WORDS: HEAT STRESS; STRESS (PHYSIOLOGY); COOLING POWER.

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TECHNICAL SUMMARY

This report is intended primarily for ventilation staff on mines, but is also of importance to management.

In the gold mining industry the assessment of heat stress is likely to be for one of three purposes: to assess either the average or the worst heat stress of a work area, or to assess the particular heat stress experienced by an individual at a specified work place. A sharp distinction is drawn between a work area and a work place. The many factors involved in the assessment of heat stress have been considered systematically and this has led to the development of recommended procedures for assessing heat stress in each of the three instances cited above. The recommended procedures are summarized in the table given below.

PURPOSE OF ASSESSMENT	RECOMMENDED MEASUREMENTS
To assess the average heat stress of a given work area for use when considering the influence of the environment on productivity, accidents, etc., but not for use in assessing the heat stroke risk.	Multiple measurements either of wet-bulb temperature and wind speed, or of the wet-kata. These should be converted to values of cooling power, which should then be averaged. The measurements should be made near where men are working, and the work area should not exceed 40 to 50 m of face including the ventilated area 5 to 10 m back from the face.
To assess the worst heat stress which may be encountered in a given work area.	The highest wet-bulb temperature measured in the work area should be used to determine the cooling power according to the curve recommended in Fig. 1. The wet-kata readings for the work area cannot be used for this purpose.
To assess the particular heat stress experienced by an individual working at a specific work place.	Measurements may be of two kinds. 1. Wet-bulb temperature and wind speed should be measured to establish the cooling power and hence the maximum safe work rate, or 2. Direct wet-kata measurements which may be converted into values of cooling power by means of Fig. 2.

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To assess the <u>worst</u> heat stress which may be encountered in a given work area.	The highest wet-bulb temperature measured in the work area should be used to determine the cooling power according to the curve recommended in Fig. 1. The wet-kata readings for the work area cannot be used for this purpose.
To assess the <u>particular</u> heat stress experienced by an individual working at a specific work place.	Measurements may be of two kinds. 1. Wet-bulb temperature and wind speed should be measured to establish the cooling power and hence the maximum safe work rate, or 2. Direct wet-kata measurements which may be converted into values of cooling power by means of Fig. 2.

1. INTRODUCTION

In the gold mining industry the assessment of environmental conditions, or heat stress, is likely to be for one of three purposes.

1. To assess the average condition, or average heat stress of a given work area (usually a stope or a development end) with a view to designing ventilation and refrigeration so as to optimise production, improve worker morale and reduce the incidence of accidents.

2. To assess the worst heat stress which may be experienced in a given work area, such as a stope or development end, in order to ensure that the heat stroke risk for people working in that area is kept within acceptable limits.

3. To assess the particular heat stress experienced by an individual working at a specified work place, e.g. a winch driver.

Work Areas: Although the difference between a work place and a work area should be clear from the examples quoted above, from a practical point of view the physical size of a work area requires closer definition. Underground workings may be extensive, and environmental conditions may vary considerably throughout these areas. If variations in environmental conditions are too large the use of average values can be misleading, or even meaningless. In order to obtain a meaningful average of the heat stress to which people are exposed, measurements should therefore be averaged for areas no larger than 40 or 50 m of working face, and including the ventilated area 5 to 10 m back from the face in which men are likely to be working. In an area of this size the wet-bulb temperature will usually vary by not more than 1°C. Averages should not be used for areas larger than this unless it has been shown that essentially constant conditions prevail throughout such areas. In the case where conditions are highly variable it would be more meaningful to indicate the number, or proportion of men who are working within specified intervals.

Measuring the Thermal Environment: When considering the measurement of heat stress there are important differences between the abovementioned three purposes for assessing the heat stress.

In the first case it is the average heat stress which is important. In the second it is the worst potential heat stress situation, such as might be found behind an obstruction or in other sheltered areas; i.e. it is the highest wet-bulb temperature and lowest wind speed which are important. In the third case it is the actual or particular heat stress experienced by a man at his work place which is important.

To a large extent this report is concerned with recommending how these heat stress measurements should be made. However, to promote a better understanding of human heat stress, the various factors upon which heat stress depends are reviewed briefly, with comments indicating their degree of importance to the gold mining industry.

2. HEAT STRESS FACTORS IN UNDERGROUND ENVIRONMENTS

The factors which contribute most to heat stress may be divided into three groups, as follows.

Environmental Factors: Air temperature and humidity, wind speed, radiant heat load, and ambient pressure.

Physical Factors: Skin surface area, clothing, body movements and work rate.

Limiting Physiological Factors: Skin area which is wet with sweat, maximum possible sweat rate, skin temperature, rectal temperature, and maximum physical working capacity.

Other factors such as age and state of health are known also to be important in the assessment of heat stress but these are not considered in this report; it is assumed that the working labour force is young and healthy. Men who are ill or older than 40 should not be exposed to limiting heat stress conditions since they are particularly susceptible to the effects of heat.

Quantitative consideration of all the other factors listed above is necessary for the proper assessment of heat stress.

2.1. Clothing

An adequate quantitative description of heat exchange between clothed men and their thermal environment has still to be developed; work is presently being devoted to this problem. In this report the assessment of heat stress is limited to essentially nude men. It must be realized that the procedures outlined later are likely to cause the heat stress level to be underestimated in situations where significant amounts of clothing are worn.

2.2. Radiant Heat Load

As humans are totally surrounded by rock in underground environments, all radiation occurs in the long wave region, and emissivity can therefore be taken equal to 1. Furthermore, as the surface temperature of the rock is seldom more than 1°C different from the dry-bulb temperature of the air, mean radiant temperature may be assumed to be equal to air temperature. Small errors in the assessment of the mean radiant temperature are not important as the radiant heat load of underground environments is small when compared to the heat produced by a working man.

Measurements have shown that the radiant area of men working underground is about 0,75 of their total surface area and the value of 0,75 is assumed in this report.

2.3. Body Movements

Body movements have the same effect as increasing the wind speed over the human body. If a person is in a zone of high wind speed then the benefit gained from movements of the body is small. However, in zones of low wind speed, movements of the body can increase substantially the cooling experienced by the man. Experiments have shown that the body movements of a working man are approximately equivalent to increasing the wind speed by 0,3 ms^{-1} (1). This effect is taken into account in the tables presented later in this report.

2.4. Wind Speed

A recent survey (3) of conditions in six large gold mines showed that nearly 40 per cent of all men underground work in areas where the wind speed is less than 0,5 m/s. Obstructions and dead spaces are inevitable, and it is impractical to ensure that every underground work place has a good wind speed.

These comments lead to the conclusion that when assessing the worst heat stress situation which could occur in a given work area it is necessary to assume a 'still air' condition. For the purpose of this report, a wind speed of 0,2 m/s is taken to be equivalent to still air. However, when assessing the average heat stress of a work area, or the actual heat stress experienced by a particular individual, the prevailing wind speeds must be taken into account.

Wind speed is one of the most important heat stress parameters of underground environments; it is accounted for quantitatively in the cooling power equations (4) and the latter may be used to establish how variations in wind speed affect the prevailing heat stress. Suitable tables of cooling power at different wind speeds have been prepared for this purpose and they are included at the back of this report.

2.5. Air Temperature and Humidity

The dry-bulb temperature is a relatively unimportant factor in hot humid underground environments. This is confirmed by the cooling power equations, as illustrated in Fig. 1. Fig. 1 shows the relatively small effect of increasing the gap between the dry- and wet-bulb temperatures from 2 to 5°C. The reduced cooling power at the higher gap is primarily the result of the increased radiant heat load on the man.

In hot working places underground the gap between the wet- and dry-bulb temperatures is usually about 2°C and very rarely as much as 5°C. Consequently, the cooling power of mining environments can be determined with sufficient accuracy from the wet-bulb temperature and wind speed, without reference to dry-bulb temperature.

For still air environments the cooling power can be determined from Fig. 1, which is drawn for an assumed air speed of 0,2 m/s.

2.6. Ambient Pressure

Although ambient pressure does affect the cooling power of underground environments the effect is not significant from the point of view of achieving a practical assessment of the average heat stress of these environments. This assertion is confirmed by the three curves for different pressures (85, 100, 115 kPa) that are presented in Fig. 1. In assessing the average heat stress of a work area, it is thus sufficient to assume a pressure of 100 kPa. However, when assessing the worst heat stress it is not sufficient to assume a standard barometric pressure of 100 kPa. Comparing curves 1, 2 and 3 in this figure shows that the cooling power of the air at a given wet-bulb temperature decreases with increasing pressure. As such, either the actual pressure should be used, or a pressure of 115 kPa may be assumed, in which case curve No. 3 in Fig. 1 should be used.

2.7. Skin Surface Area

For a particular rate of doing a specific type of work, the rate of metabolic heat generation is fixed, therefore, a man with a large surface area will experience less heat stress than a man with small surface area since his greater area will enable him to dissipate more easily the metabolic heat being generated. For Black men, the skin surface area is usually within the range 1,5 m^2 to 2,1 m^2; an average value of 1,8 m^2 is usually assumed, as is the case in this report.

2.8. Maximum Physical Working Capacity

It is known that men who have a high physical working capacity are better able to cope with the effects of heat stress. In this regard physical working capacity is similar in effect to skin surface area; for a fixed work rate an increase in either of these factors would be equivalent to a reduction in the heat stress. The cooling power values used in this report are based on a random distribution of physical work capacities.

However, in most mines the allocation of labour is based on a physical selection test, so that men with high physical working capacities are assigned to the more strenuous tasks. Where this practice is in force the margin of safety will be greater than would otherwise be the case.

2.9. Work Rate

For the purpose of evaluating heat stress, the rate at which a man works must be converted into a rate of metabolic heat generation. For a man of average size (skin surface area of 1,8 m^2) light work would correspond to a metabolic rate of about 115 W/m^2, moderate work to approximately 175 W/m^2 and hard work to about 280 W/m^2. Since an average skin area is assumed, it will be appreciated that the above rates of metabolic heat generation are subject to an uncertainty of ± 15 percent.

A guide to the work rate corresponding to different mining tasks is given in Table I.

TABLE I GRADING OF MINING TASKS FOR HEAT STRESS PURPOSES

LIGHT WORK	MODERATE WORK	HARD WORK
Winch Sweep Spanner Walking Drain-Cleaning	Stonewall Box Machine Boring Timbering Team Leader	Tramming Shovelling

2.10. Maximum Possible Sweat Rate

Acclimatized men are able to produce more than enough sweat for the purpose of body cooling. Unfortunately not all of this sweat evaporates from the skin surface since some of it drips off without providing any cooling benefit. Maximum possible sweat rate is therefore not a limiting factor in the mining industry, when working with acclimatized men. With unacclimatized men the maximum possible sweat rate is a limiting factor because such men are not able to sweat for long periods at the rates required. However, this report is concerned with hot environments and with acclimatized men only.

2.11. Skin Area Wet with Sweat

It is known that acclimatized men can produce more sweat than can be evaporated in the typical hot humid conditions found underground and hence it is assumed that the entire skin area is wet.

2.12. Limiting Skin and Rectal Temperatures

These two parameters are fundamental to the assessment of what constitutes an acceptable level of heat stress. It has been shown that rectal temperature, skin temperature and rate of metabolic heat generation bear well defined relationships with each other (4). For the one-in-a-million chance of the rectal temperature of an acclimatized workman rising above 40°C, mean skin temperature and rate of metabolic heat generation are related linearly, as shown in Fig. 3. This graph is used in this report to define a limiting value of mean skin temperature for any given work rate. The tables of cooling power at the end of the report take this variation of skin temperature into account.

3. COOLING POWER OF THE ENVIRONMENT

For a man to be able to work steadily for a full shift it is necessary that the cooling power of the environment must equal or exceed a minimum value which is equal to the rate at which he is generating heat. All the factors discussed above must be taken into account when calculating cooling power. The minimum cooling power equation that is developed in reference (4) is based on the particular values of the factors which have been discussed above; furthermore the tables at the back of this report derive from this equation.

It must be emphasized that different scales of cooling power (for the same wet-bulb temperature and wind speed) will be needed if situations different from those referred to above are involved.

For example, in the case of clothed men, or unacclimatized men, the same scales cannot be expected to apply. Also, a change in the risk criterion would result in different scales. Hence as new knowledge becomes available, or new criteria are introduced it may be necessary to introduce different scales of cooling power.

In order to avoid confusion it would be desirable to designate the presently used scale perhaps as the "A" scale of cooling power, with subsequent scales to be designated appropriately.

3.1. Wet Kata

In typical mining environments wet-kata readings have been found to correlate closely with the values of cooling power that are given in the table at the end of this report (4). The relationship between wet-kata and cooling power is given in Fig. 2. This means that wet-kata readings can be interpreted in the same way as the cooling power in the assessment of heat stress, and that the wet-kata thermometer can be used to measure the actual cooling power directly.

It should be emphasized, though, that the interpretation of kata readings would differ for men who are not acclimatized since their physiological response to heat stress is substantially different from that of acclimatized men, as has been pointed out in section 2.10 above.

4. RECOMMENDED PROCEDURE FOR MEASURING HEAT STRESS

Before setting about the problem of measuring the heat stress it is most important that the purpose for making the measurements be established clearly, since the procedure for measuring the heat stress will vary, depending on the purpose.

4.1. To Assess the Average Heat Stress

The average heat stress of a given work area should be assessed from a number of measurements of the wet-bulb temperature and wind speed, or from a number of measurements with the wet-kata thermometer. The measurements should be made in the immediate vicinity of where men are found to be working. The values of wet-bulb temperature and wind speed should be converted into equivalent values of cooling power using the tables provided, and these values of cooling power should then be averaged. The measured wet-kata readings can be averaged before being converted into equivalent values of cooling power, although strictly speaking it should be done the other way round because the relation between the two (Fig. 2) is not exactly linear.

It should be pointed out that although this procedure will give a valid estimate of the average heat stress, it would be wholly incorrect to conclude that when the average work rate equals the average cooling power, there will be only a one-in-a-million risk of the rectal temperature of any man rising above 40°C. Average heat stress levels may, however, prove useful in correlating the heat stress of underground work areas with factors such as productivity (2) accidents, absenteeism and general morale.

4.2. To Assess the Worst Heat Stress

The worst heat stress in a given work area can be assessed from wet-bulb temperature measurements without measurements of wind speed. The highest measured wet-bulb temperature should be used to determine the cooling power of the environment from the curve recommended in Fig. 1.

This value of cooling power is indicative of the worst heat stress situation which any man may encounter while working in the given work area. Should his rate of metabolic heat generation equal the value of the cooling power read from Fig. 1 then it is possible that while performing his usual work the man may be exposed to a one-in-a-million risk of his rectal temperature rising above 40°C. Should the determined value of cooling power be less than the rate of metabolic heat generation then a potentially dangerous situation could arise, and appropriate remedial measures should therefore be taken.

4.3. To Assess the Heat Stress at a Specific Work Place

In order to assess the heat stress at a specific work place, either the wet-bulb temperature and wind speed, or the wet-kata, should be measured in the immediate vicinity of the man. In the former case the tables should be used to establish the cooling power, and in the case of a wet-kata reading, Fig. 2, will enable conversion into cooling power.

Should the metabolic rate of the individual be greater than the cooling power, then either the work rate must be reduced or the cooling power of the environment must be increased. Should work rate and metabolic rate be equal there will be a one-in-a-million chance that the rectal temperature of the man will rise above 40°C.

5. SUMMARY OF RECOMMENDATIONS

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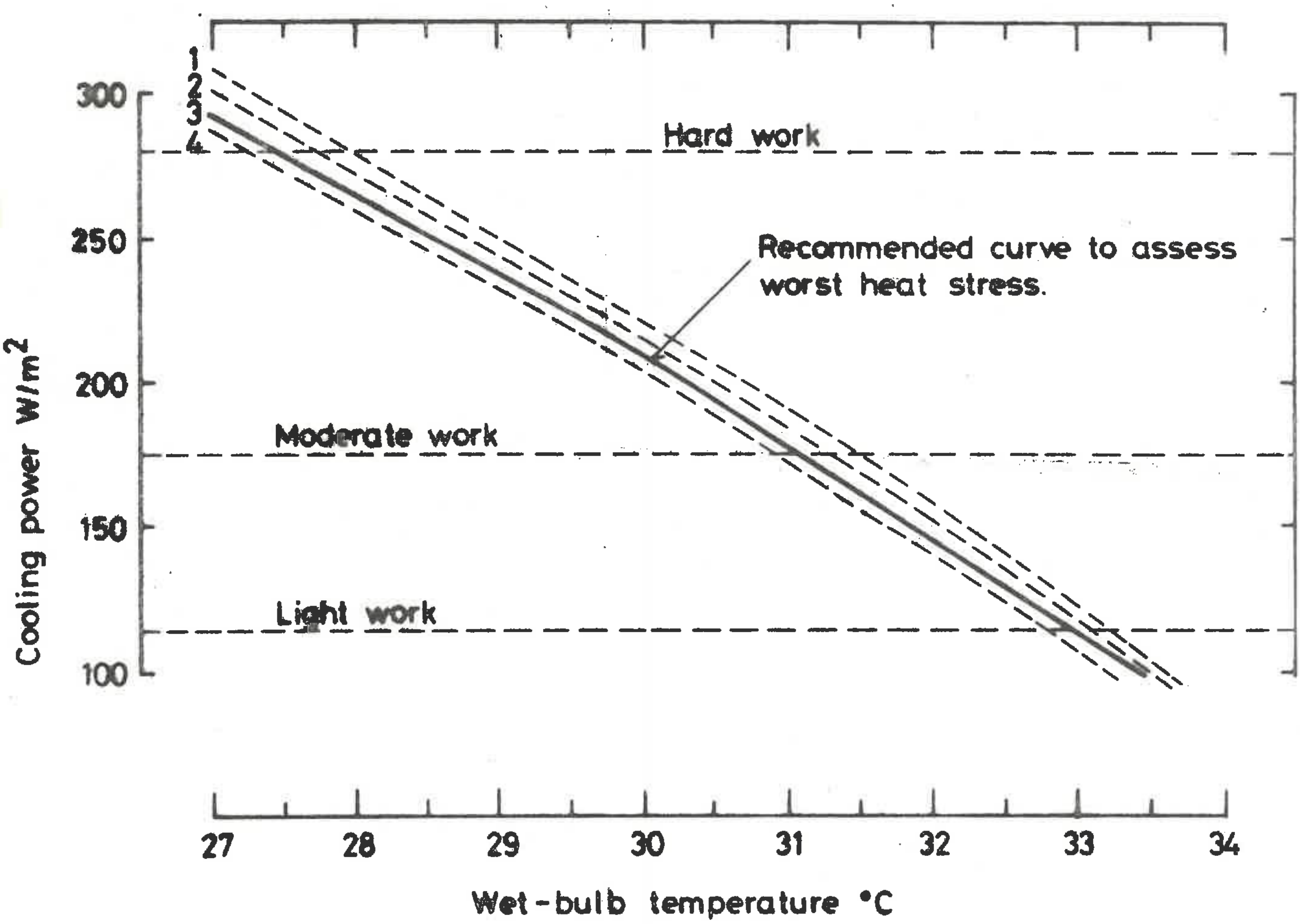

FIG. 1. COOLING POWER AS A FUNCTION OF WET-BULB TEMPERATURE FOR STILL AIR (WIND SPEED = 0,2 m/s)

LEGEND:	CURVE	PRESSURE kPa	$(t_{db} - t_{wb})^{o}C$
	1	85	2
	2	100	2
	3	115	2
	4	100	5

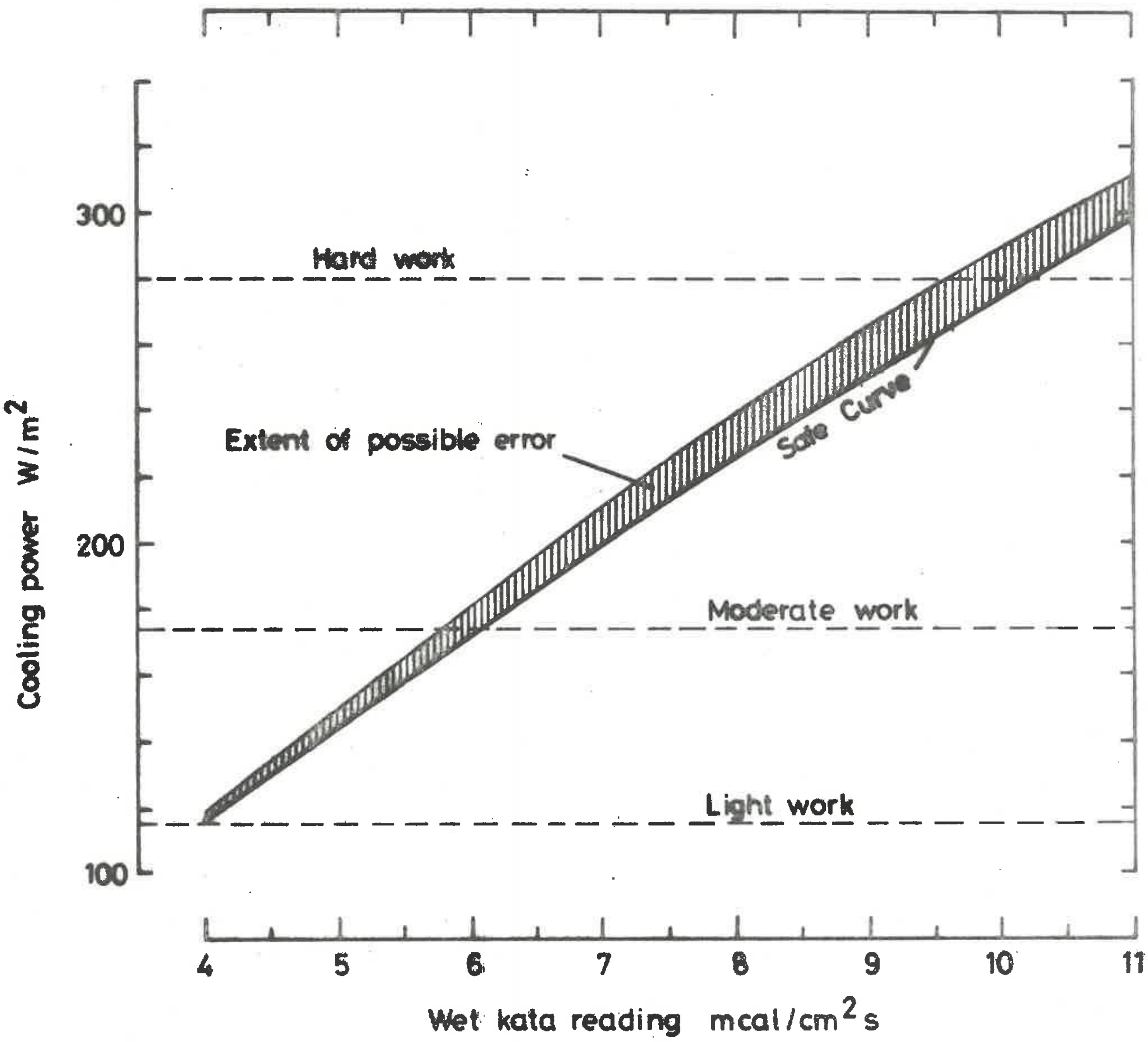

FIG. 2. COOLING POWER AS A FUNCTION OF WET KATA READING

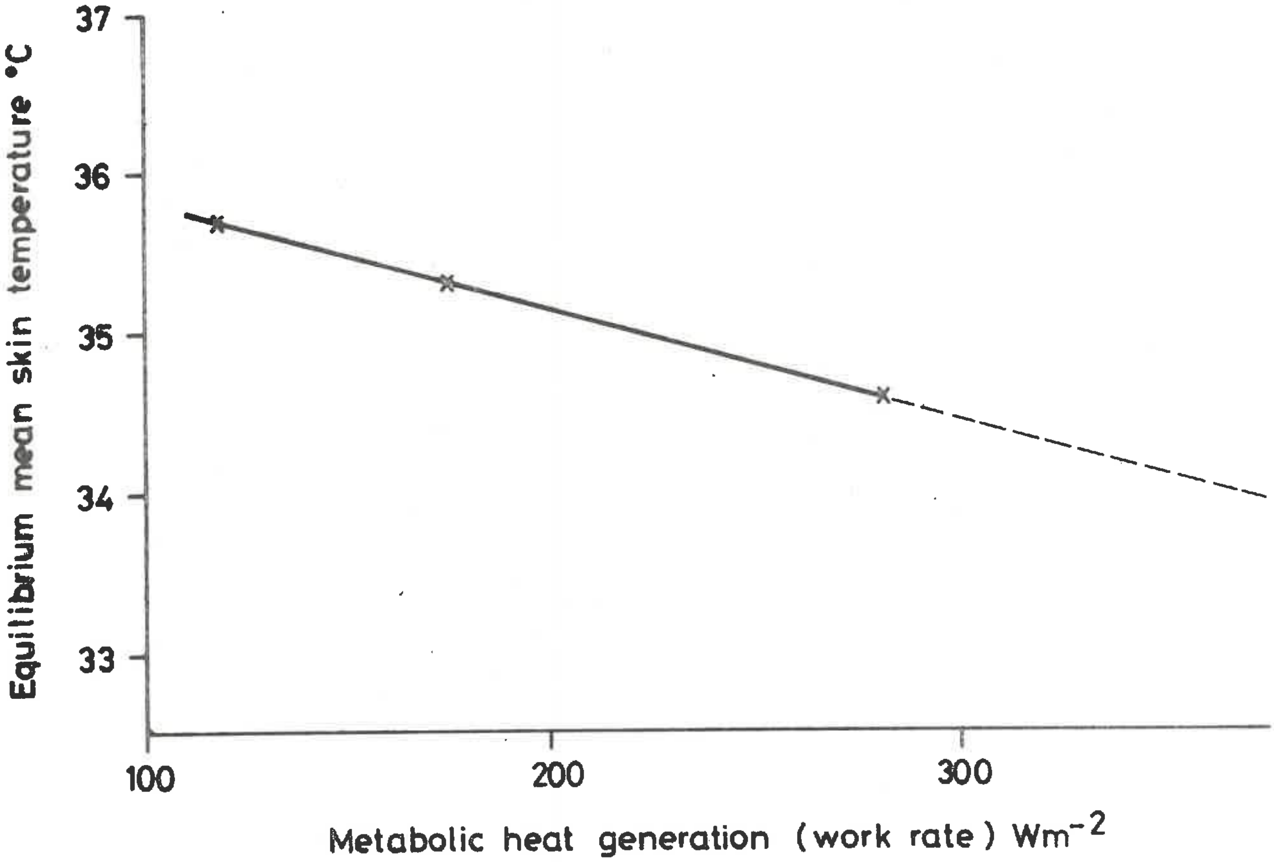

FIG. 3. EQUILIBRIUM MEAN SKIN TEMPERATURES WHICH CORRESPOND TO THE 1×10^{-6} PROBABILITY OF AN INDIVIDUAL WORKER'S RECTAL TEMPERATURE RISING ABOVE 40°C AT VARIOUS RATES OF METABOLIC HEAT GENERATION.

TABLES OF COOLING POWER W/m^2

WETTED AREA FRACTION - 1,0; MRT = DB = WB + 2°C; PRESSURE = 100 kPa

WHEN COOLING POWER = METABOLIC RATE, THE PROBABILITY OF RECTAL TEMPERATURE RISING ABOVE 40°C = ONE-IN-A-MILLION

AIR SPEED (Metres per second)

WET BULB Deg.C	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.2	2.4	2.6	2.9	3.0	3.5	4.0	4.5
25.0	351	378	402	424	444	462	479	495	510	523	537	549	561	572	593	593	603	612	621	638	654	669	683	696	726	752	775
25.1	348	375	399	421	440	459	476	491	506	520	533	545	557	568	579	589	593	608	617	634	650	664	678	691	721	747	770
25.2	346	372	396	418	437	455	472	488	502	516	529	541	553	564	575	585	594	604	613	630	645	660	674	686	716	741	764
25.3	343	370	393	415	434	452	469	484	499	512	525	537	549	560	571	581	590	599	608	625	641	655	669	682	711	736	759
25.4	341	367	390	412	431	449	465	481	495	509	521	534	545	556	566	576	586	595	604	621	636	650	664	677	705	731	753
25.5	338	364	388	409	428	445	462	477	491	505	518	530	541	552	562	572	582	591	599	616	631	646	659	672	700	725	748
25.6	336	362	385	406	425	442	458	474	488	501	514	526	537	548	558	568	577	586	595	611	627	641	654	667	695	720	742
25.7	333	359	382	402	421	439	455	470	484	497	510	522	533	544	554	564	573	582	591	607	622	636	649	662	690	715	737
25.8	330	356	379	399	418	435	451	466	480	494	506	518	529	540	550	559	569	578	586	602	617	631	644	657	685	709	731
25.9	328	353	376	396	415	432	448	463	477	490	502	514	525	535	546	555	564	573	582	598	613	626	640	652	680	704	726
26.0	325	350	373	393	412	429	445	459	473	486	498	510	521	531	541	551	560	569	577	593	608	622	635	647	674	699	720
26.1	323	348	370	390	409	425	441	456	469	482	494	506	517	527	537	547	556	564	573	588	603	617	630	642	669	693	715
26.2	320	345	367	387	405	422	438	452	466	478	490	502	513	523	533	542	551	560	568	584	598	612	625	637	664	688	709
26.3	317	342	364	384	402	419	434	448	462	475	486	498	509	519	529	538	547	555	564	579	594	607	620	632	659	682	703
26.4	315	339	361	381	399	415	430	445	458	471	483	494	504	515	524	534	542	551	559	574	589	602	615	627	653	677	698
26.5	312	336	358	377	395	412	427	441	454	467	479	490	500	510	520	529	538	546	554	570	584	597	610	621	648	671	692
26.6	310	334	355	374	392	408	423	437	451	463	475	486	496	506	516	525	533	542	550	565	579	592	605	616	643	666	686
26.7	307	331	352	371	389	405	420	434	447	459	471	482	492	502	511	520	529	537	545	560	574	597	600	611	637	660	651
26.8	304	328	349	368	385	401	416	430	443	455	467	477	488	498	507	516	525	533	541	556	569	582	595	606	632	655	675
26.9	301	325	346	365	382	398	413	426	439	451	463	473	484	493	503	511	520	528	536	551	565	577	589	601	626	649	669
27.0	299	322	343	361	379	394	409	422	435	447	459	469	479	489	498	507	515	524	531	546	560	572	584	596	621	643	663
27.1	296	319	340	359	375	391	405	419	431	443	454	465	475	485	494	503	511	519	527	541	555	567	579	590	616	633	657
27.2	293	316	337	355	372	387	402	415	427	439	450	461	471	480	489	498	506	514	522	536	550	562	574	585	610	632	652
27.3	291	313	334	352	369	384	398	411	424	435	446	457	467	476	485	494	502	510	517	532	545	557	569	580	605	626	646
27.4	288	310	330	348	365	380	394	407	420	431	442	453	462	472	481	489	497	505	513	527	540	552	564	575	599	621	640
27.5	285	307	327	345	362	377	391	404	416	427	438	448	458	467	476	485	493	500	508	522	535	547	558	569	594	615	634
27.6	282	305	324	342	358	373	387	400	412	423	434	444	454	463	472	480	488	496	503	517	530	542	553	564	588	609	628
27.7	280	302	321	339	355	369	383	396	408	419	430	440	449	458	467	475	483	491	498	512	525	537	548	559	582	603	622
27.8	277	299	318	335	351	366	379	392	404	415	426	436	445	454	463	471	479	486	493	507	520	532	543	553	577	598	616
27.9	274	296	315	332	348	362	376	388	400	411	421	431	441	450	458	466	474	481	489	502	515	526	537	548	571	592	610
28.0	271	293	312	329	344	359	372	384	396	407	417	427	436	445	454	462	469	477	484	497	510	521	532	542	566	586	604
28.1	269	290	308	325	341	355	368	380	392	403	413	423	432	441	449	457	465	472	479	492	504	516	527	537	560	580	598
28.2	266	287	305	322	337	351	364	377	388	399	409	418	427	436	444	452	460	467	474	487	499	511	521	531	554	574	592
28.3	263	284	302	319	334	348	361	373	384	395	405	414	423	432	440	448	455	462	469	482	494	505	516	526	549	569	586
28.4	260	281	299	315	330	344	357	369	380	390	400	410	419	427	435	443	450	457	464	477	489	500	511	520	543	562	580
28.5	257	278	296	312	327	340	353	365	376	386	396	405	414	423	431	438	445	452	459	472	484	495	505	515	537	556	574
28.6	255	274	292	308	323	337	349	361	372	382	392	401	410	418	426	433	441	448	454	467	479	490	500	509	531	550	563
28.7	252	271	289	305	319	333	345	357	368	378	387	397	405	413	421	429	436	443	449	462	473	484	494	504	526	544	561
28.8	249	268	286	301	316	329	341	353	364	374	383	392	401	409	416	424	431	439	444	457	468	479	489	499	520	538	555
28.9	246	265	282	298	312	325	337	349	359	369	379	388	396	404	412	419	426	433	439	452	463	473	483	493	514	532	549
29.0	243	262	279	295	309	322	334	345	355	365	374	383	392	399	407	414	421	428	434	446	458	468	478	487	508	526	543
29.1	240	259	276	291	305	318	330	341	351	361	370	379	387	395	402	409	416	423	429	441	452	463	472	481	502	520	536
29.2	237	256	273	288	301	314	326	337	347	357	366	374	382	390	399	405	411	419	424	436	447	457	467	476	496	514	530
29.3	234	253	269	284	298	310	322	333	343	352	361	370	378	385	393	400	406	413	419	431	442	452	461	470	490	509	524
29.4	231	250	266	281	294	306	318	329	339	348	357	365	373	381	388	395	402	408	414	425	436	446	456	464	484	502	517
29.5	228	246	263	277	290	303	314	324	334	344	352	361	369	376	383	390	397	403	409	420	431	441	450	459	478	496	511
29.6	225	243	259	274	287	299	310	320	330	339	348	356	364	371	378	385	392	398	404	415	425	435	444	453	472	489	505
29.7	223	240	256	270	283	295	306	316	326	335	343	352	359	367	373	380	387	393	399	410	420	430	439	447	466	483	498
29.8	220	237	252	266	279	291	302	312	322	330	339	347	354	362	369	375	381	388	393	404	414	424	433	441	460	477	492
29.9	217	234	249	263	275	287	298	300	317	326	334	342	350	357	364	370	376	382	388	399	409	418	427	435	454	471	405

TABLES OF COOLING POWER W/m²

WETTED AREA FRACTION - 1,0; MRT = DB = WB + 2°C; PRESSURE = 100 kPa

WHEN COOLING POWER = METABOLIC RATE, THE PROBABILITY OF RECTAL TEMPERATURE RISING ABOVE 40°C = ONE-IN-A-MILLION

WET BULB Deg.C	AIR SPEED (Metres per second) 0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.2	2.4	2.6	2.8	3.0	3.5	4.0	4.5
30.0	214	231	246	259	272	283	294	304	313	322	330	338	345	352	359	365	371	377	383	394	403	413	421	430	448	464	479
30.1	211	227	242	256	268	279	290	299	309	317	325	333	340	347	354	360	366	372	379	388	398	407	416	424	442	458	472
30.2	208	224	239	252	264	275	286	295	304	313	321	328	336	342	349	355	361	367	372	383	392	401	410	418	436	452	466
30.3	205	221	235	248	260	271	282	291	300	308	316	324	331	339	344	350	356	362	367	377	387	396	404	412	430	445	459
30.4	201	218	232	245	256	267	277	287	296	304	312	319	326	333	339	345	351	356	362	372	381	390	398	406	424	439	453
30.5	198	214	228	241	253	263	273	283	291	299	307	314	321	328	334	340	346	351	356	366	376	384	392	400	417	432	446
30.6	195	211	225	237	249	259	269	278	287	295	302	309	316	323	329	335	340	346	351	361	370	379	387	394	411	426	439
30.7	192	208	221	234	245	255	265	274	282	290	298	305	311	318	324	330	335	341	346	355	364	373	381	388	405	420	433
30.8	189	204	218	230	241	251	261	270	278	286	293	300	307	313	319	325	330	335	340	350	359	367	375	382	399	413	426
30.9	186	201	214	226	237	247	257	265	273	281	288	295	302	309	314	319	325	330	335	344	353	361	369	376	392	406	419
31.0	183	198	211	223	233	243	252	261	269	276	284	290	297	303	309	314	319	325	329	339	347	355	363	370	386	400	412
31.1	180	194	207	219	229	239	248	257	264	272	279	286	292	298	303	309	314	319	324	333	342	349	357	364	379	393	406
31.2	177	191	204	215	225	235	244	252	260	267	274	281	287	293	298	304	309	314	319	327	336	344	351	358	373	387	399
31.3	174	188	200	211	221	231	240	248	255	263	269	276	282	288	293	298	304	308	313	322	330	338	345	351	367	380	392
31.4	170	184	196	207	217	227	235	243	251	258	265	271	277	283	288	293	299	303	307	316	324	332	339	345	360	373	385
31.5	167	181	193	204	214	223	231	239	246	253	260	266	272	277	283	288	293	297	302	310	318	326	333	339	354	367	378
31.6	164	177	189	200	210	218	227	234	242	249	255	261	267	272	278	283	287	292	296	305	312	320	326	333	347	360	371
31.7	161	174	185	196	206	214	222	230	237	244	250	256	262	267	272	277	282	286	291	299	307	314	320	327	341	353	364
31.8	158	170	182	192	201	210	218	226	233	239	245	251	257	262	267	272	276	281	285	293	301	308	314	320	334	346	357
31.9	155	167	178	188	197	206	214	221	228	234	240	246	252	257	262	266	271	275	280	287	295	302	308	314	328	340	350
32.0	151	164	174	184	193	202	209	217	223	230	235	241	246	252	256	261	266	270	274	282	289	295	302	309	321	333	343
32.1	148	160	171	180	189	197	205	212	219	225	231	236	241	246	251	256	260	264	268	276	283	289	296	301	314	326	336
32.2	145	157	167	177	185	193	201	207	214	220	226	231	236	241	246	250	254	259	262	270	277	283	289	295	308	319	329
32.3	142	153	163	173	181	189	196	203	209	215	221	226	231	236	240	245	249	253	257	264	271	277	283	289	301	312	322
32.4	138	150	160	169	177	185	192	198	204	210	216	221	226	230	235	239	243	247	251	259	265	271	277	282	294	305	315
32.5	135	146	156	165	173	180	187	194	200	205	211	216	221	225	230	234	238	242	245	252	259	265	270	276	288	298	303
32.6	132	142	152	161	169	176	183	189	195	200	206	211	215	220	224	228	232	236	239	246	253	258	264	269	281	291	300
32.7	128	139	148	157	164	172	178	184	190	196	201	206	210	214	219	223	226	230	234	240	246	252	258	263	274	284	293
32.8	125	135	144	153	160	167	174	180	185	191	196	200	205	209	213	217	221	224	228	234	240	246	251	256	267	277	286
32.9	122	132	141	149	156	163	169	175	180	186	191	195	200	204	208	211	215	219	222	228	234	240	245	250	260	270	279
33.0	118	128	137	145	152	158	165	170	176	181	185	190	194	199	202	206	209	213	216	222	228	233	238	243	254	263	271
33.1	115	124	133	141	148	154	160	166	171	176	180	185	189	193	197	200	204	207	210	216	222	227	232	236	247	256	264
33.2	112	121	129	137	143	150	155	161	166	171	175	179	183	187	191	194	198	201	204	210	215	220	225	230	240	249	257
33.3	108	117	125	132	139	145	151	156	161	166	170	174	178	182	185	189	192	195	198	204	209	214	219	223	233	241	249
33.4	105	114	121	128	135	141	146	151	156	161	165	169	173	176	180	183	186	189	192	198	203	208	212	216	226	234	242
33.5	101	110	117	124	130	136	142	146	151	156	160	164	167	171	174	177	180	183	186	192	196	201	205	210	219	227	234
33.6	98	106	113	120	126	132	137	142	146	150	154	158	162	165	168	172	175	177	180	185	190	195	199	203	212	220	227
33.7	94	102	110	116	122	127	132	137	141	145	149	153	156	160	163	166	169	171	174	179	184	188	192	196	205	212	219
33.8	91	99	106	112	117	123	127	132	136	140	144	147	151	154	157	160	163	165	168	173	177	182	185	189	198	205	212
33.9	88	95	102	108	113	118	123	127	131	135	139	142	145	148	151	154	157	159	162	167	171	175	179	182	190	198	204
34.0	84	91	98	103	109	114	118	122	126	130	133	137	140	143	146	148	151	153	156	160	164	168	172	175	183	190	196
34.1	81	87	94	99	104	109	113	117	121	125	128	131	134	137	140	142	145	147	150	154	159	162	165	169	176	183	185
34.2	77	84	90	95	100	104	108	112	116	119	123	126	129	131	134	136	139	141	143	148	151	155	159	162	169	175	181
34.3	73	80	86	91	95	100	104	107	111	114	117	120	123	126	128	131	133	135	137	141	145	148	152	155	162	168	173
34.4	70	76	81	86	91	95	99	102	106	109	112	115	117	120	122	125	127	129	131	135	138	142	145	148	154	160	165
34.5	66	72	77	82	86	90	94	97	101	104	106	109	112	114	116	119	121	123	125	128	132	135	138	141	147	153	159
34.6	63	68	73	78	82	86	89	92	95	98	101	104	106	108	110	113	115	117	118	122	125	128	131	134	140	145	150
34.7	59	64	69	73	77	81	84	87	90	93	96	98	100	102	105	107	109	110	112	115	118	121	124	127	132	137	142
34.8	56	61	65	69	73	76	79	82	85	88	90	92	95	97	99	100	102	104	106	109	112	115	117	120	125	130	134
34.9	52	57	61	65	68	71	74	77	80	82	85	87	89	91	93	94	96	98	99	102	105	108	110	112	118	122	126