

'RUSTERS'. THE CORROSIVE ACTION OF PALMAR SWEAT: II. PHYSICAL AND CHEMICAL FACTORS IN PALMAR HYPERHIDROSIS

O. Jensen and E. Nielsen¹

*Department of Dermatology, Municipal Hospital, Copenhagen, and ¹Corrosion Institute
Park Allé, Glostrup, Denmark*

Abstract. When measuring sweating rates, close correspondence was found with the clinical estimation of hyperhidrosis. Corrosion was seen to increase with increasing sweat rates, reaching its maximum after an assumed rise in the actual sodium chloride concentration on the skin surface due to evaporation of water. The findings confirm that hyperhidrosis is of primary importance in the constitution of a 'ruster', and are also in good agreement with experimental reports. The small variations in palmar skin pH had no influence on the degree of corrosion; nor had the character of the metal surface. Of the two types of metal studied, corrosion was much more severe on the type having the lowest concentration of copper, thus confirming that increasing copper concentrations have a positive effect in reducing corrosion rates. At 50-60% relative humidity (RH) corrosion increased as time elapsed, whereas at 40% RH no corrosion developed on a sweat-contaminated plate. When exposed to 75% RH, metal samples became severely corroded in the course of a few days. Protective methods for the avoidance of rust are mentioned, with special emphasis on frequent handwashing.

Key words: Corrosion of metal by palmar sweat; Palmar hyperhidrosis; pH of skin surface; Chemical composition of steel; Character of the metal surface; Humidity; Prevention

The finding of hyperhidrosis of the palms in all 'rusters' (6) prompted the present study, in which an attempt was made to objectify the hyperhidrosis by the measuring of sweating rates. These findings were correlated to the corrosion produced by corrosion test procedures under various conditions. Further, an attempt was made to study the possible influence upon corrosion, of skin pH, the chemical composition of the steel and the character of the metal surface. The influence of humidity and methods of prevention are also discussed.

MATERIALS

The eight participating 'rusters', 3 patients with palmar hyperhidrosis and 8 control persons have been described earlier (6).

METHODS

Measurement of sweat rate

First the hands were dried with a towel. Each hand was put into a cotton glove and covered with a plastic glove which was closed around the wrist by a rubber band. The persons were then presented with a series of mental arithmetic tests for 10 min (9). Each person thereafter rubbed his hands, so that most of the sweat produced would be absorbed by the cotton gloves. After removal of both gloves simultaneously the rubber band was tied so as to enclose the cotton glove inside the plastic glove and thus avoid evaporation. The specimens, previously weighed on a microbalance, were then reweighed and the difference calculated.

After clinical improvement following 3 weeks of treatment with aluminium chloride hexahydrate in absolute ethyl alcohol, as described in the previous article (6), a second measurement of the sweat rate was performed using another difficult series of mental arithmetic tests.

Corrosion tests

The palms and volar surfaces of the fingers were gently pressed against carefully rinsed steel plates measuring 20×20 cm for one minute. Two different types of steel were used (Table I), the difference in carbon content giving rise to different metallographic structures (Fig. 1a and 1b). On type 1 steel the test was performed in the following three stages on both polished and unpolished surfaces: 1) Without washing and without occlusion of the hands. Washing of the hands was not allowed for 4 hours before the examination. 2) Without washing, but after occlusion of the hands in plastic gloves for 10 min. 3) After washing of the hands in demineralized water followed by air drying and occlusion in plastic gloves for 10 min. On type 2 steel only stage 2 was performed and only on polished surfaces.

The eight 'rusters' underwent the complete investigation including all the above-mentioned stages, whereas the patients with palmar hyperhidrosis and the control persons underwent only stages 1 and 2 performed on type 1 steel.

The plates were exposed at 21-23°C and 50-60% relative humidity (RH). The extent of corrosion was evaluated 2 weeks and 2 months later, when photographs were taken.

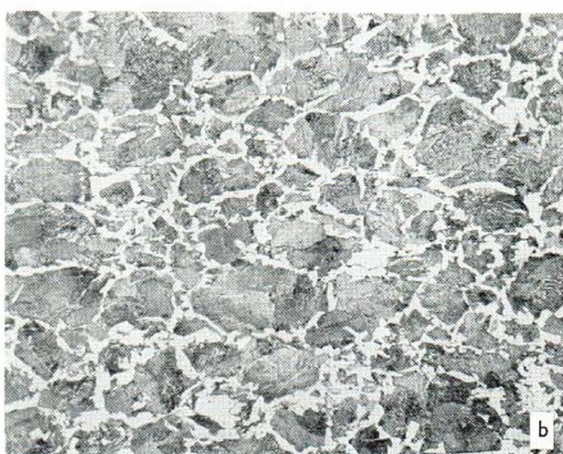


Fig. 1. Metallographic structure. (a). Type 1 steel ($\times 210$). The very low carbon content makes the structure ferritic (pure iron). (b). Type 2 steel ($\times 210$). The carbon content of 0.41% gives a structure with pearlite (iron and

cementite (iron carbide)), seen as the dark areas, and ferrite. The copper, which has the greatest influence on the corrosive behaviour of the steel, is dissolved in the steel.

By coincidence a plate from a 'ruster' was placed in a room with a low RH (40%). It was later exposed to higher RH (75%).

Measurement of skin pH

A flat glass electrode (Radiometer No. G242C) was placed on the left palm of both 'rusters' and patients in a drop of saturated aqueous potassium chloride 2 cm from a calomel reference electrode (1). Four readings were made at intervals of 1/2 min, and the mean value was calculated.

RESULTS

In all 'rusters' the tendency to corrode metal had been observed during the first half-year of apprenticeship and had continued through the years as skilled workers. The corrosion would appear 1–7 days after handling the metal and worsen during the following weeks. Polished surfaces were said to be the most susceptible. The 'rusters' had to take often inconvenient precautions (i.e. use gloves, lubricate the hands with oil or clean polluted specimens with kerosine). These precautions did not suffice for one of the 'rusters', who had been discharged from three jobs (7).

Measurement of sweat rate (right + left hand)

Highest values were obtained from patients with palmar hyperhidrosis (mean 1.500 g/10 min). Between 'rusters' (mean 0.933 g/10 min) and control persons (mean 0.577 g/10 min) the difference was significant ($0.02 > p > 0.01$). After treatment of the

hyperhidrosis a considerable reduction in sweat rates was seen both in 'rusters' (mean 0.352 g/10 min=43%) and in patients (mean 0.813 g/10 min=56%).

Corrosion tests

Both 'rusters' and patients with palmar hyperhidrosis caused development of corrosion on metal surfaces corresponding to palms and fingers. Judged according to the visible deposition of rust, 5 of the 'rusters' and the 3 patients were found to cause severe corrosion, while the remainder of the 'rusters' produced a more moderate corrosion. Most corrosion was produced in stages 1 and 2. Occlusion of the hands (stage 2) only caused a dubious increase in corrosion, and after washing of the hands (stage 3) only slight to moderate corrosion was seen. The control persons did not produce any corrosion during stage 1, but in stage 2, slight corrosion was found corresponding to fingertips in two persons.

The extent of corrosion produced by each 'ruster' was almost identical on both polished and unpolished surfaces and in all three stages. Only slight corrosion developed on type 2 steel in all 'ruster' cases.

On comparing the photographs taken after 2 weeks and 2 months, corrosion was seen to be more pronounced after 2 months, in all cases (Fig. 2).

The plate kept at low RH developed only negligible corrosion during the 2 subsequent months.



Fig. 2. Corrosion test (stage 2) on a 'ruster' carried out on sheet of 'mild', polished steel. Photograph taken 2 weeks (left) and 2 months (right) after the print was made. Corro-

sion is seen to start with pinpoint specks corresponding to the openings of the sweat ducts on the cristae cutis.

When thereafter exposed to high RH, severe corrosion developed within a few days.

pH measurement

Somewhat higher values were found for the 'rusters' (mean 6.2, range 5.6–6.9) than for the control persons (mean 5.8, range 5.2–6.4).

DISCUSSION

On comparing the sweat rates with the corrosion tests, a close correlation was found. The 5 'rusters' and the 3 patients with severe hyperhidrosis as judged by clinical estimation (6), also had the highest sweat rates and caused the heaviest corrosion in the tests. The 3 'rusters' with moderate hyperhidrosis had lower sweat rates and caused corrosion to a lesser degree. This tendency was seen in all the stages of the corrosion tests.

Maximal corrosion was produced in stages 1 and 2 in the corrosion tests. In stage 1, washing of the hands was not allowed and sweat was assumed to be produced continuously and be concentrated by evaporation of water. This seemed to be confirmed

by the results in stage 3, where only slight to moderate corrosion occurred after washing of the hands, implying that freshly produced sweat with a lower salt concentration had a much lesser corrosive effect on the plate. In stage 2, occlusion of the unwashed hands was assumed to increase the amount of freshly produced sweat on the skin surface, yet only a doubtful increase in corrosion was seen. Probably the actual sodium chloride concentration was so high that it was not influenced by the lower concentrations in freshly produced sweat. In this way the present study is in good agreement with other experimental investigations. When using artificial sweat solutions, the degree of corrosion has been shown to be proportional to the quantity of corrosive salts deposited on the metal surface (5) and to the concentration of sodium chloride (4). In a hyperhidrotic state, more sweat (and thus more sodium chloride) will be deposited per time unit on the metal surface, and through evaporation of water the actual concentration of sodium chloride on the skin surface will increase.

It was the opinion of the 'rusters' in this study, that polished surfaces were more susceptible to cor-

Table 1. Chemical composition of steel plates

	Type 1 (%)	Type 2 (%)
Carbon	0.09	0.41
Silicium	—	0.22
Manganese	0.37	0.75
Phosphorus	0.011	0.017
Sulphur	0.023	0.020
Chromium	0.03	0.06
Nickel	—	0.003
Copper	0.02	0.06
Vanadium	—	0.001
Aluminium	0.001	0.002

rosion than were ground surfaces. However, this was not confirmed by the corrosion tests, where almost identical degrees of corrosion occurred, irrespective of the character of the surface. Maybe corrosion on polished surfaces is more easily recognized and more often causes defects on the specimens.

The chemical composition of the steel is obviously of great importance, as corrosion was found to be far heavier on type 1 steel than on type 2. This difference can be correlated to the content of copper, as increasing concentrations of copper up to 0.3% tend to diminish corrosion through the formation of heavy soluble basic copper salts (10). In this study the concentration of copper was three times greater in type 2 steel than in type 1 (Table 1). The other constituents mainly influence the mechanical properties of the steel and have no—or little—influence on the corrosion in the initial stages, i.e. the duration of exposure in this study.

pH values in the acid range tend to produce more corrosion than pH in the neutral or alkaline range. In the range $4 < \text{pH} < 10$ this is of only secondary importance (10). Because of the buffering capacities of the palmar surface, wide variations are not likely to be seen (4). From studies on artificial sweat solutions only a minor increase of corrosion was found at pH 5.2 compared with pH 8.0 (4). The pH results in the present study are in good agreement with other reports (2, 4) as also is the fact that the moderate variations found did not influence the corrosion (2, 4).

A rather low RH was deliberately chosen in order to imitate conditions of daily work. The RH will influence the corrosion of an unpolluted steel surface as follows. Up to 60–70 RH the corrosion rate will increase only slightly, due to the lack of a

'water film' on the steel surface. At 60–70% RH it will be possible to form—by capillary condensation and from the small quantities of salts—increasing amounts of water on the surface and hence the corrosion will increase (10). If salts such as sodium chloride are present, the corrosion will start at lower RH. The chlorides on the steel surface will be in equilibrium with the humidity in the surrounding atmosphere, and in most cases this will result in a higher concentration of sodium chloride on the steel surface than that directly resulting from the sweat deposition (3). Sodium chloride will be corrosive at RH's of 40–60%, for instance (and of course at higher RH's). Calcium chloride on the other hand will form a solution on the steel surface at much lower RH values, thus being corrosive in very dry atmospheres (3).

These considerations are also in good agreement with the observations in this study. In particular it should be mentioned that the steel plate with sweat kept at 40% RH suffered no corrosion, but the pollution did result in corrosion when the plate was exposed to 75% RH.

Sodium chloride on the steel surface will form an electrolyte which is a prerequisite for the corrosion processes. The chlorides will therefore only take part in the process, but not be consumed. Thus the process will continue as long as the surface is polluted with the chlorides. This fact was noticed by the 'rusters' and confirmed in this study.

General precautions against rusting include washing of the hands, avoidance of excessive salt intake, an ample supply of drinking water at the place of work, frequent changing of protective gloves, and cool working conditions (18–21°C) with a RH at about 50% (2, 8). A lower RH is not to be recommended, as the corrosion might then appear later, possibly after dispatch of the polluted specimen from the manufacturer. Special emphasis should be placed on frequent hand washing, as the concentration of sodium chloride would increase on a hyperhidrotic palm. If these precautions do not suffice, topical application of aluminium chloride hexahydrate in a 25% solution in absolute ethyl alcohol should be tried (6).

ACKNOWLEDGEMENTS

Thanks are due to the Copenhagen Branch of the Union of Danish Metalworkers and the Technical School of the Iron and Metal Industry, Copenhagen.

The study was supported by grants from the Danish Medical Research Council and the Danish Hospital Foundation for Medical Research, Region of Copenhagen, the Faroe Islands and Greenland.

REFERENCES

1. Behrendt, H. & Green, M.: Patterns of skin pH from birth through adolescence, pp. 32-33. Charles C. Thomas, Springfield, Ill., 1971.
2. Buckley, W. R. & Lewis, C. E.: The 'ruster' in industry. *J Occup Med* 2: 23, 1960.
3. Champion, F. A.: Corrosion testing procedures, 431 pp. Chapman & Hall, London, 1964.
4. Collins, K. J.: The corrosion of metal by palmar sweat. *Br J Industr Med* 14: 191, 1957.
5. Eisler, S. J. & Faigen, H. L.: Investigation of synthetic fingerprint solutions. *Corrosion* 10: 237, 1954.
6. Jensen, O.: 'Rusters'. The corrosive action of palmar sweat. I. Sodium chloride in sweat. *Acta Dermatovener (Stockholm)* 59: 135, 1979.
7. Jensen, O.: 'Rustfingre'. Et tilfælde hos en dansk metalarbejder. Accepted for publication in *Ugeskr Laeg*.
8. Lind, S. E.: Metaller korrosion genom svett och dess förhindrande, p. 40. Swedish Corrosion Institute, Stockholm, 1969.
9. Quatralle, R. P., Stoner, K. L. & Felger, C. B.: A method for the study of emotional sweating. *J Soc Cosmet Chem* 28: 91, 1977.
10. Uhlig, H. H.: Corrosion and corrosion control, 371 pp. John Wiley & Sons, New York & London, 1963.

Received August 18, 1978

O. Jensen, M.D.
Department of Dermatology
The Municipal Hospital
Ø. Farimagsgade 5
DK-1399 Copenhagen K
Denmark