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"ATMOSPHERIC CORROSION TESTS ALONG THE NORWEGIAN-RUSSIAN BORDER"

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SUMMARY

A bilateral exposure programme has been carried out along the Norwegian-Russian border in 1990 and 1991, in order to provide a quantitative evaluation of the effect of sulphur pollutants on the atmospheric corrosion of important materials in sub-arctic climate.

The results of the corrosion tests of metal materials has shown that also in subarctic climate the metal corrosion is dependent of the atmospheric corrosivity, which is due to man-made emissions. The corrosion rate (C) of steel was best described by equations which combined the effects of SO_2 and time of wetness (TOW)

$$C = (a_1 + a_2 C_{SO_2}{}^{a_3})\ TOW^{a_4}$$

Because of the temperature range found in the subarctic, the importance of defining the real time of wetness on the surface will increase. The common approximation of assuming the time of wetness to be defined by relative humidity above 80% and temperatures above 0° C works well in temperate climates, but a more detailed and refined definition is needed in subarctic climate, where long periods with temperatures close to 0° C are more frequent.

The high sensitivity of metal corrosion to the level of pollution in a SO_2 polluted air allows the construction of a model which determines the limiting target SO_2 level.

ATMOSPHERIC CORROSION TESTS ALONG THE NORWEGIAN-RUSSIAN BORDER

1 PURPOSE OF THE BILATERAL EXPOSURE PROGRAMME

The purpose of the programme is quantitatively to evaluate the effect of sulphur pollutants on the atmospheric corrosion of important metals in subarctic climate. The programme is based on a bilateral exposure programme on test sites along the Norwegian-Russian border and was carried out in co-operation between the Institute of Physical Chemistry of the Russian Academy of Sciences, Moscow, and the Norwegian Institute for Air Research.

2 DESCRIPTION OF THE PROGRAMME

The exposure panels are placed near the regular air pollution measuring sites along the Norwegian-Russian border. The sites are a part of the bilateral agreement on co-operation with respect to the environment and the measurement sites are equipped with SO_2 monitors and in part also with meteorological instruments. Norwegian sites are Viksjøfjell, Karpdalen, Svanvik, Kobbfoss and Noatun. Russian sites are marked as Sov1, Sov2 and Sov3. Figure 1 shows a map of the area and exposure sites. Norwegian sites Viksjøfjell, Karpdalen and Svanvik also have a NILU-designed aerosol trap for chloride and magnesium. This is done to have information about exposure to salt particle deposition at the sites.

<u>Materials</u>

Flat samples (10 x 15 cm):

- Steel	3 parallels for yearly exposure
	3 x 4 = 12 parallels for 3 months' exposure
	3 x 12 = 36 parallels for monthly exposure

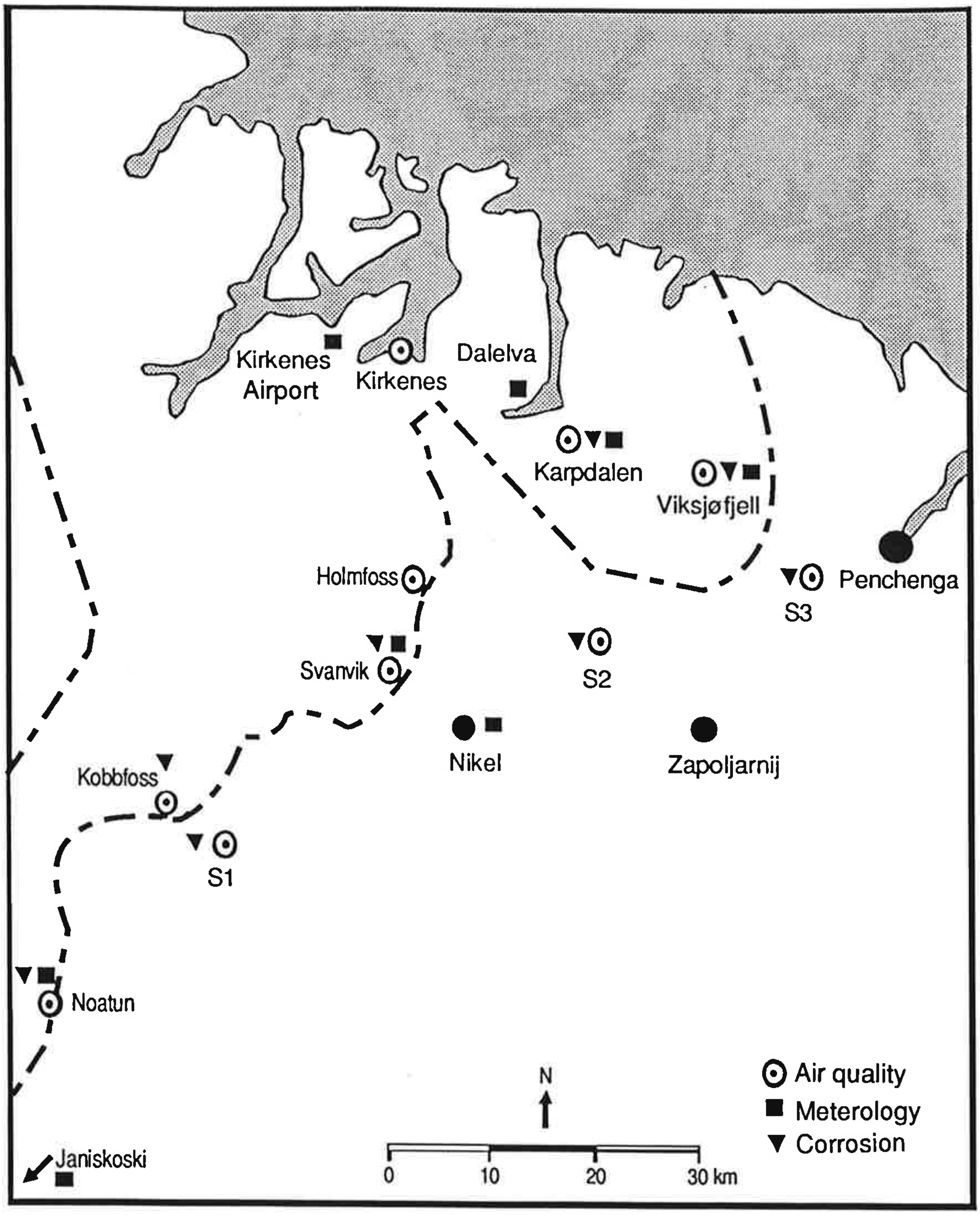

Figure 1: Map of the test sites and the type of measurements performed at the sites.

The steel used follows the Swedish standard SS 1316.

- Galvanized steel 2 parallels for yearly exposure (275 g Zn/m^2)
- "Aluzinc" 3 parallels for yearly exposure (185 g Aluzinc/m^2 chromated)
- Zinc 3 parallels for yearly exposure

Helix samples (ISO/DIS 9226):

- Galvanized steel (30 μm Zn) 3 parallels for yearly exposure

- Steel coated with "Galfan" 3 parallels for yearly exposure (95% Zn + 5% Al, 230 g/m^2)

- Aluminium 3 parallels for yearly exposure

The panels are facing south with a 45° angle and the helices are mounted vertically on a horisontal plate at the upper rim of the panel.

The mass loss determinations and the chloride and magnesium analyses were carried out in one laboratory (NILU). The period of the exposure programme was June 1990-May 1991.

3 MAIN TASKS ACCOMPLISHED IN THE WORK

a) The study of the specific features of atmospheric corrosion in subarctic climate and the development of a model of the effect of suphur pollutants and meteorological factors on the atmospheric metal corrosion;
b) Evaluation of the possibility to determine the limiting target level for metals by the use of steel.

4 PHYSICO-CHEMICAL DESCRIPTION OF ATMOSPHERIC CORROSION

Most types of metal corrosion develops by an electrochemical mechanism. Therefore the corrosion processes in the atmosphere are dependent on the presence of electrolyte films on the metal surface. Even in a "pure" humid atmosphere the corrosion process may develop at a low rate. The time of wetness (Rh > 80%, T > 0° C) is taken to be the parameter determining the possibility of the development of atmospheric corrosion.

Among the corrosion-active impurities sulphur dioxide - one of the main air pollutants of antropogenic nature - is the main factor accelerating atmospheric corrosion. In coastal and sea atmosphere sea water aerosols are a corrosion-active factor. Other compounds are nitrogen oxides, ammonium, acidity, dust, precipitates of aerosols with different chemical. Deposition of the corrosion-active substances depend on the concentrations in ambient air and wind velocity as well as of the structure and the exposed situation of the corroding material.

5 THEORETICAL PREREQUISITS FOR THE ANALYSIS OF THE RESULTS AND DEVELOPMENT OF THE MODEL OF ATMOSPHERIC CORROSION

The kinetics of atmospheric corrosion in the atmosphere containing sulphur dioxide at a low concentration may schematically be represented in Figure 2, curve 2, (curve 1 for an ideally pure atmosphere), and are presented as corrosion rate against time in Figure 3. The curve can be divided in three characteristic phases:

Phase I: At this initiation step there is not enough pollutant accumulated on the metal surface, which is coated with an oxide film. The corrosion rate is low. As the pollutant accumulates in the electrolyte film destruction of the oxide film begins and the corrosion rate increases (the transition region from phase I to phase II), Figure 2 and 3.

Phase II: The destruction of the metal occurs at its maximum rate, which during this phase is almost constant.

Phase III: The layer of corrosion products formed at the surface begins to cover the metal surface and delay the corrosion process. The corrosion rate begins to decrease.

The duration of phase I depends on the pollutant level in the atmosphere. The accumulation of the pollutant on the surface occurs faster with increasing concentration of sulphur dioxide. (In Figure 1 $C_5 > C_4 > C_3 > C_2$.) The corrosion rate in phase I as well as in phase II will be higher, while the duration of the sections will be smaller. In the limiting case, at the pollutant level C_5 phase I is practically equal to zero.

The ratio between the phases is also different. The constant corrosion rate with time may be observed for some metals for several years (phase II).

From the curves in Figure 2 plots of the corrosion versus the SO_2 concentrations can be made. In Figure 4 this is illustrated for two different times a and b. On the axis "corrosion" one may find the values corresponding to corrosion for a defined time in an ideally pure and rural atmosphere, and on the axis "SO_2", we can find the level, at which intensive corrosion destruction of metal begins (pollutant threshold).

According to the definition of the target level in references (1, 2), target level is the pollution level for which the material used can last for a defined time. If the specified lifetime is increased we have to reduce the target level by pollutants to meet the new specification. For increasing lifetime, the target level will approach the limiting target level, which depends only on the physico-chemical properties of the air-oxide film on the metal, determining the sensitivity of the material to the air pollutant.

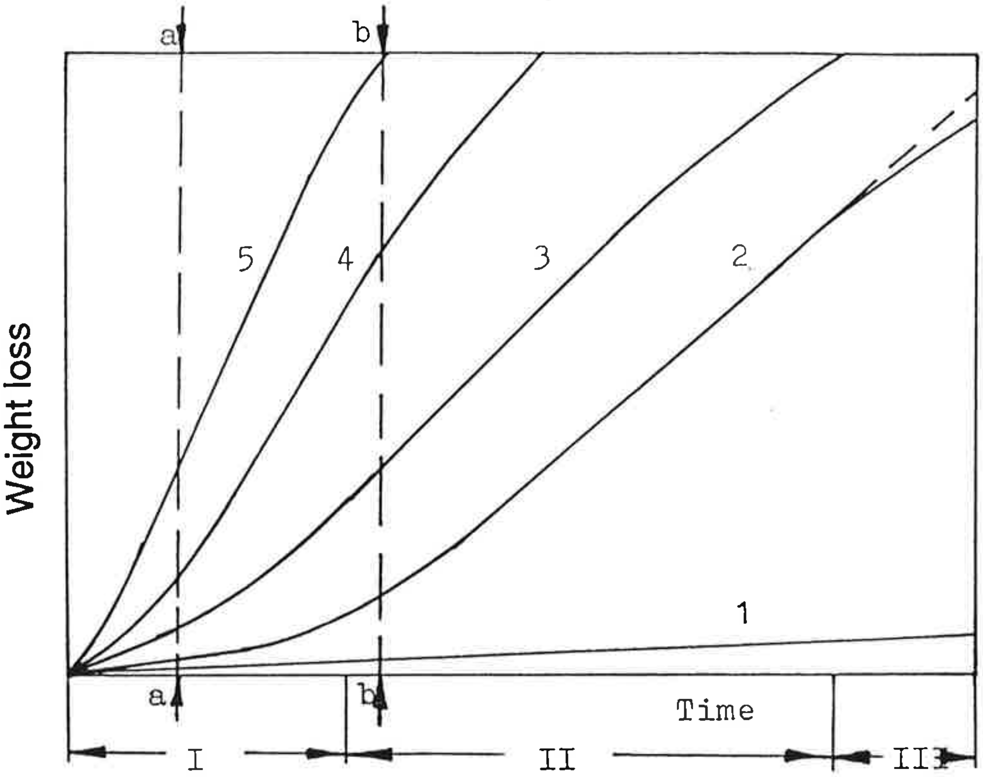

Figure 2: The kinetic development of atmospheric corrosion of metal at different SO_2 levels.
$(C_{SO_2})_1 = 0$; $(C_{SO_2})_5 > (C_{SO_2})_4 > (C_{SO_2})_3 > (C_{SO_2})_2$;

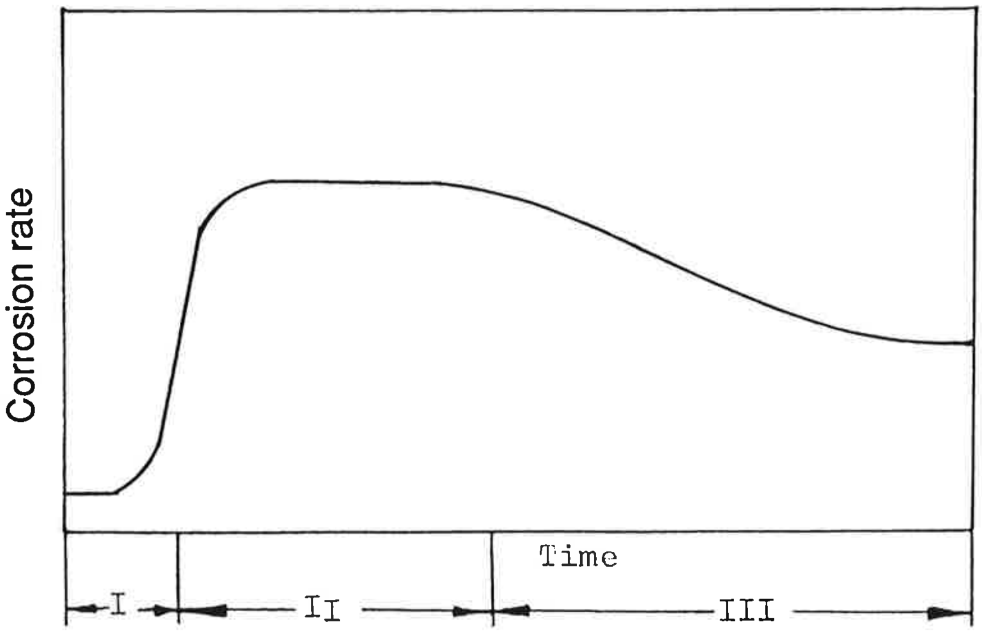

Figure 3: The kinetic curve of rate of atmospheric corrosion of metal.

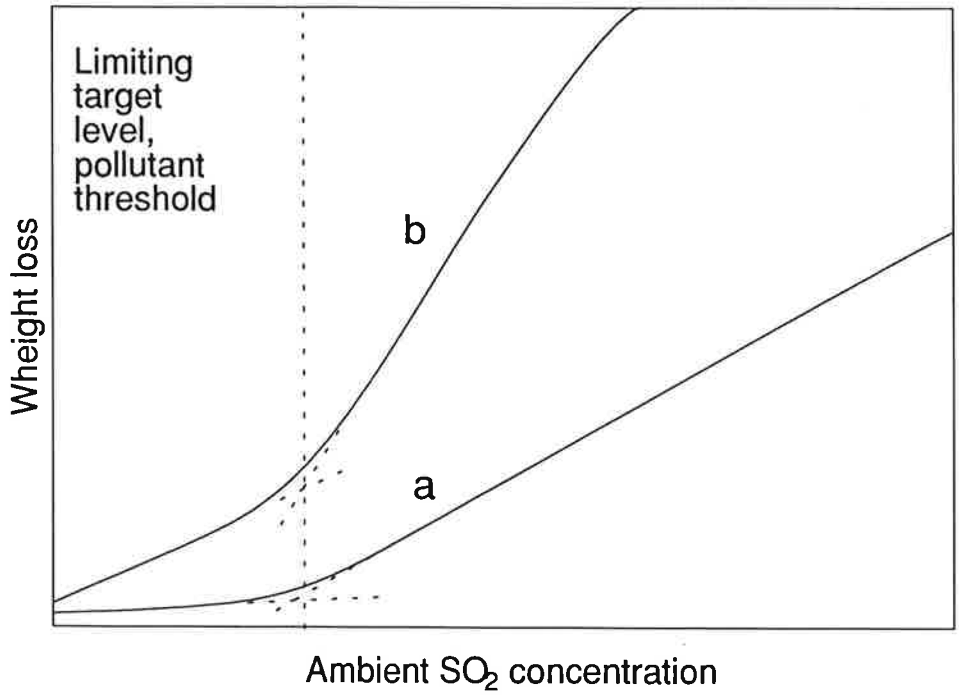

Figure 4: Atmospheric corrosion of metal vs. the SO_2 level.

The target level may differ from the critical level because metal corrosion may occur at a low rate also in a pure atmosphere. In general, the destruction of the oxide film begins at a defined critical load of an air pollutant caused by pollutants accumulated on the surface. However, in open atmosphere the surfaces are periodically washed with rain water, and the pollution load will be reduced. For long time exposure the changes in the load will give a mean load correlated to the pollution level in the air.

The determination of the limiting target levels for materials and their comparison with critical levels for other ecosystems are of both scientific and practical interest. However, it is difficult to establish a complete curve like curve a in Figure 4 under real conditions in order to determine the limiting target level. The necessary conditions for this are:

a) a set of test sites with increasing SO_2 concentration levels,

b) the time of wetness (TOW) on the test sites should not differ appreciably, which, as a rule, only can be fulfilled in exposure programme carried out in local regions (in other cases the TOW must be taken into account),

c) the time of the tests should correspond to the limits of phase I of the axis "Time", curve 2, Figure 2, if the information about the limiting target level should be defined (each metal has its optimum test time).

Other corrosion-active impurities, various combinations of SO_2 levels and TOW, short-term time peaks of SO_2 in background regions may make the determination of the limiting target level difficult. A decrease of the SO_2 level during exposure below the limiting target level may for some metals lead to a partial or complete passivation of the surface (formation of the adsorption or phase protective film), which will also affect the kinetics of corrosion.

In the present work on atmospheric tests in a local region there is a number of favourable conditions: A set of test sites with different SO_2 levels. Practically the same climatic conditions and a wide range of the test steel panels exposed for different periods. The possibilities for evaluation of the limiting target level for steel or determination of the range where it may lie are therefore favourable.

It is obvious that the models describing the mass losses of steel depending of the SO_2 level, do not need to be linear. The linear approximation can only be used in separate part of curves a and b in Figure 4.

6 EXPERIMENTAL RESULTS AND DISCUSSION

6.1 TEMPERATURE, RELATIVE AIR HUMIDITY, TIME OF WETNESS

The temperature and relative air humidity measurements were made at Viksjøfjell, Svanvik and Noatun, entirely embracing the test region. The data on temperature and relative humidity given in Annex A (Table 1a, 2a) and kinetics of their change for a year (Figure 5, 6) for these sites are similar, and for Noatun and Svanvik they are practically identical. A small difference in the monthly average temperature values (lower values in spring-summer 1990 and higher values in January-February 1991) were observed at Viksjøfjell (measurements are not available for December). Minimum positive temperatures were twice observed at Viksjøfjell, once in Svanvik and thrice in Noatun. The relative humidity at Viksjøfjell in autumn-winter were somewhat higher than that in Svanvik and Noatun (the relative humidity measurements at Viksjøfjell were rejected for June, July and December 1990 and January 1991).

The time of wetness values (TOW = T >0°, Rh >80%) determined for Viksjøfjell and Svanvik (Annex A, Table 3a) are not significantly different from each other. From November 1990 through March 1991 the TOW values were equal or nearly equal to 0. According to the generally accepted concept of TOW, this indicates negligible atmospheric corrosion processes on metals during this period. Taking into account the geographical position of the sites, we have used the TOW values obtained at Viksjøfjell for Karpdalen and Sov3, and those obtained at Svanvik for Noatun, Kobbfoss, Sov1 and Sov2. For August and September where data from Viksjøfjell were missing, the results from Svanvik were used without corrections.

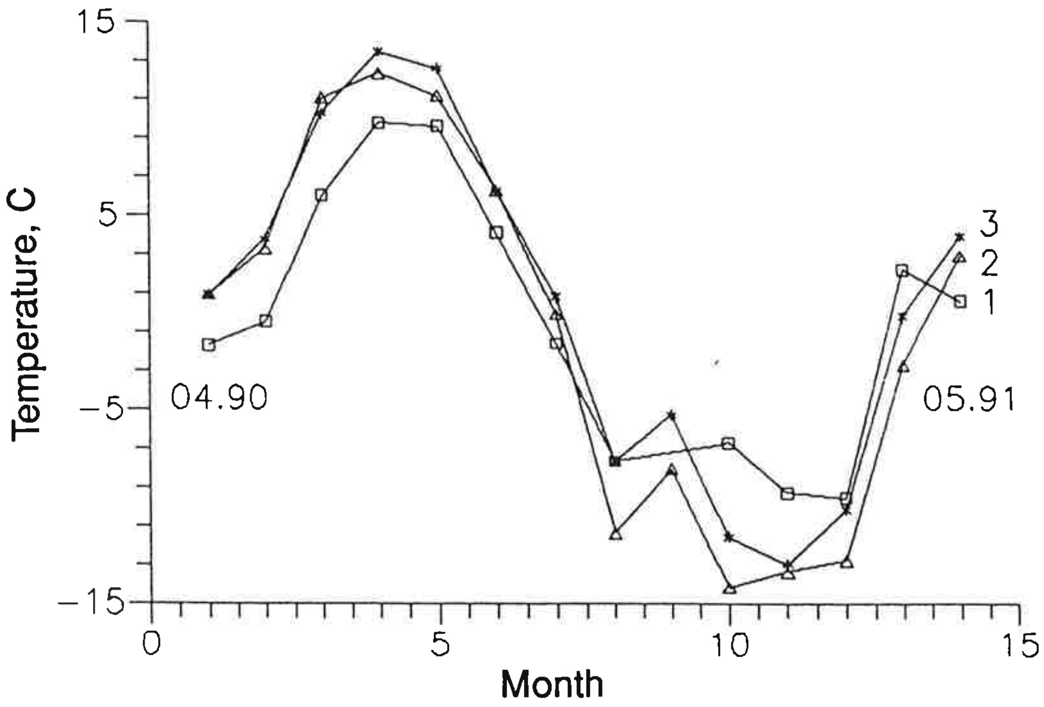

Figure 5: Monthly average temperatures at Viksjøfjell (1), Svanvik (2) and Noatun (3). April 1990-May 1991.

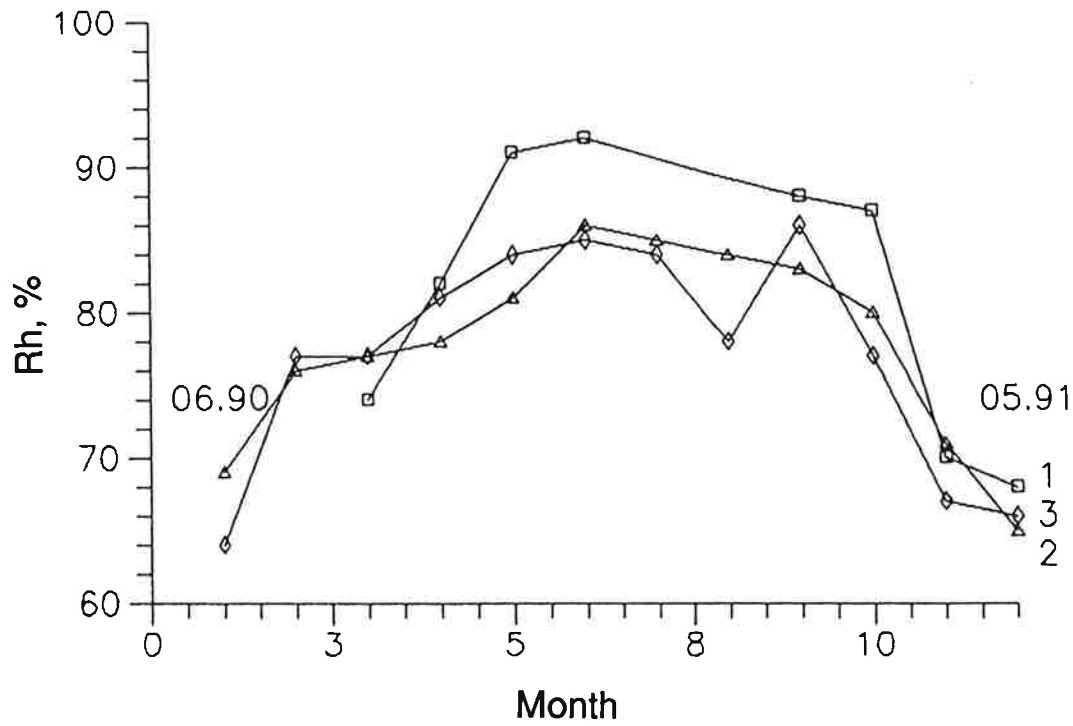

Figure 6: Monthly average relative air humidity at Viksjøfjell (1), Svanvik (2) and Noatun (3). June 1990-May 1991.

6.2 SULPHUR DIOXIDE AND WIND

The SO_2 levels at test sites are depending of the emissions, speed and direction of the wind, as well as on the distance from the sources (mainly, Nickel and Zapolyarny (3)). During the exposure period the concentrations varied over a wide range, Annex A, Table 4a. This is illustrated by the monthly average SO_2 values, maximum values, the number of days with SO_2 above 50 and 100 $\mu g/m^3$.

The wind parameters (wind speed and wind direction) were measured at Viksjøfjell (25 m above ground) and at Svanvik (10 m above ground) during the whole test period. The wind conditions at Viksjøfjell (Appendix B) were characterized by the prevailing 210°-240° directions. Relatively strong winds (> 6 m/s) prevailed during the period and calm conditions did not occur.

The wind conditions at Svanvik were characterized by the prevailing 180°-240° directions. The winds of 30°-90° and 30°-60° directions prevailed in June and July 1990, respectively. In May 1991 the winds of the 30°-90°, 210°-240° directions prevailed. The wind speed is lower than that at Viksjøfjell and was not above 4 m/s. The calm periods had long duration, from November 1990 to April 1991 they account for 23-30% of the time.

Because of the wind conditions in the test region, the highest SO_2 levels in Sov2, Sov3, Viksjøfjell and Karpdalen were observed during the period from August 1990 to April 1991. During June 1990, July 1990 and May 1991 the monthly average SO_2 levels were low and lied within the range 8-11, 7-13, 11-13 and 5-8 $\mu g/m^3$ respectively.

6.3 DRY DEPOSITION OF Cl AND Mg

The measurements of the dry deposition of Cl were made at Viksjøfjell and Karpdalen during June 1990-April 1991 and at Svanvik during June 1990-May 1991 (Annex A, Table 5a). The dry deposition of Cl and Mg increases in the order Svanvik > Karpdalen > Viksjøfjell. Table 1 allows us to compare the values of dry deposition of Cl obtained for these sites and those determined in ref. (4) for pure rural (Zvenigorod), urban (Moscow) and coastal atmospheres of the Black Sea (Batumi and Sarafovo) and the Barents Sea (Murmansk). According to ref. (4) the contribution of the dry deposition to the atmospheric corrosion process in Moscow is insignificant, however, it becomes noticeable at the Black Sea coast. Therefore, the dry deposition of Cl at Viksjøfjell may contribute to the increased atmospheric corrosion, especially during November 1990-March 1991.

Dry deposition of Cl is known to increase at wind speeds above 6 m/s (5). Therefore an attempt was made to find the correlation between the monthly time of wind > 6 m/s of the prevailing directions at Viksjøfjell and dry deposition of Cl, Table 2.

Table 1: Comparison of chloride dry deposition between three Norwegian test sites at the Russian border, three Russian, one Georgian and one Bulgarian site. Rural (Zvenigorod), urban (Moscow) and coastal atmospheres of the Black Sea and the Barents Sea.

Country	Norway			Russia			Georgia	Bulgaria
Station	Viksjøfjell	Karpdalen	Svanvik	Zvenigorod	Moscow	Murmansk	Batumi	Sarafovo
Dry deposition Cl, $\mu g/m^2d$	2850	1180	706	160	620	3000	18500	4100
Period	11 months		1 year					

Norway - NILUs aerosol trap
Russia and Bulgaria - method of dry cloth (7).

Table 2: Coefficients of correlation of dry depositon of Cl vs. time of wind > 6 m/s at Viksjøfjell during June 1990-April 1991 (except December 1990).

Direction	210°	210° and 240°	240°
R	-0.093	0.504	0.619

The highest coefficient of correlation is observed for the wind direction 240°. A marked descrepancy between the dry deposition of Cl and time of the wind 240° takes place during November 1990, Figure 7, therefore the R value for the wind direction 240° is not very high. In sea water the ratio between Cl and Mg as an average is found to be 14.9. The calculated ratio Cl/Mg is above 14.9 for almost every month during the measuring year. A reasonable conclusion is that an additional source of chloride besides sea water occurs in the area. The correlation coefficient between chloride and high wind speed from 240°, indicates a source of chloride in the Nikel area.

To make a final conclusion at this point further measurement must be carried out. If Nikel is a primary source area, parallel measurement of the dry deposition of both SO_2 and chloride should be carried out on all test sites available.

6.4 PRECIPITATION

Atmospheric precipitations were measured at Svanvik and Noatun during the whole test period, in Karpdalen during January 1991-May 1991, Table 6a-8a. The monthly precipitation amounts as well as the yearly values are generally low, and the differences cannot have a marked effect on the rate of atmospheric corrosion, Table 3.

In most cases pH of the precipitation was below 5, the pH of the precipitation increases in the order Noatun > Svanvik > Karpdalen, Table 6a-8a. The lowest pH values were observed in

Karpdalen in May 1991 (pH = 3.11). the difference in the pH values is about 0.5-1 pH unit. Undoubtedly, the increased acidity of the precipitation contributed to the increase of the metal corrosion rate. It is difficult, however, to evaluate the quantitative role of pH due to the minor differences in the pH values for different test sites.

The concentration of the sulphate ion in the precipitation samples at Noatun and Svanvik were similar, as well as their yearly average values (2.01 and 1.81 mg/l respectively). In Karpdalen the concentration of the sulphate ion in the precipitations was higher. An analogous conclusion may be also made for Cl ions. Periodically the concentration of Cl increased abruptly. Table 4 shows the weekly Cl values of the precipitation, when the concentration of the Cl ions were above 5 mg/l. The frequency of the cases and the quantity of Cl ions in the precipitation decreased in the order Karpdalen > Noatun > Svanvik. The Cl/Mg and Cl/Na ratios were similar to sea water

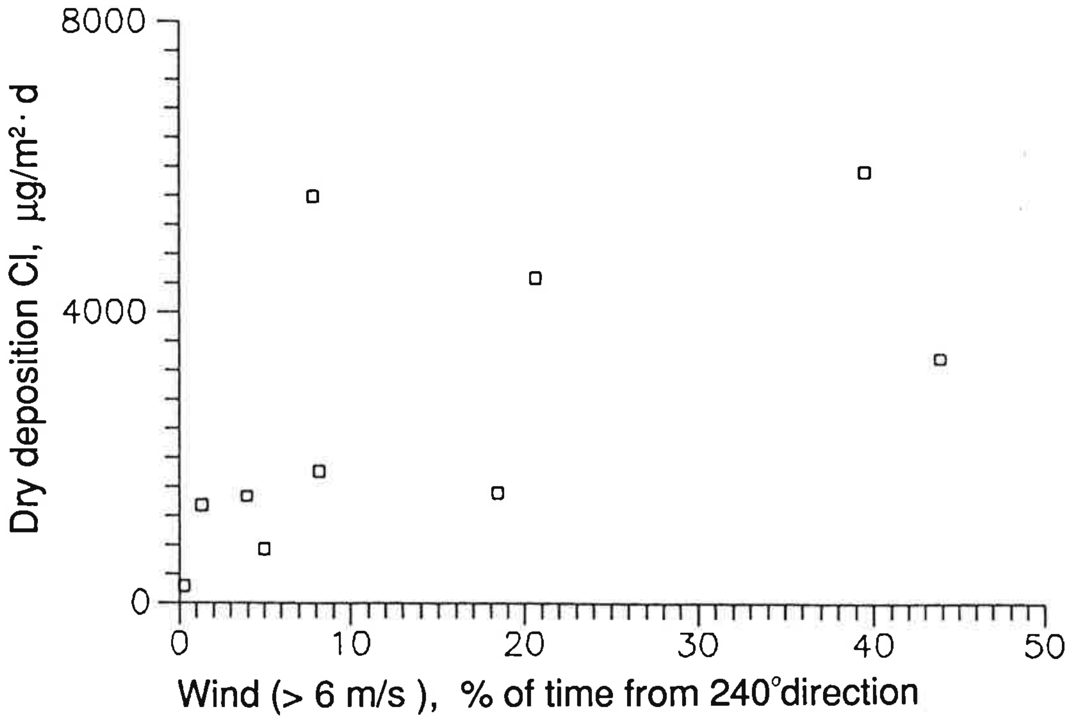

Figure 7: Monthly values of dry deposition Cl at Viksjøfjell for the period June 1990-May 1991 vs. time of wind > 6 m/s from 240° direction.

Table 3: Monthly and yearly values of precipitation in Noatun, Svanvik and Karpdalen, mm.

Station	Period												
	6/90	7/90	8/90	9/90	10/90	11/90	12/90	1/91	2/91	3/91	4/91	5/91	Year
Noatun	17.6	39.1	41.0	12.5	13.5	18.8	15.0	9.7	3.5	25.9	0	18.9	215.5
Svanvik	22.6	22.3	61.4	14.5	9.8	21.2	21.0	17.7	3.6	21.2	0	21.6	236.9
Karpdalen	-	-	-	-	-	-	-	15.2	4.1	23.0	0	8.5	-

Table 4: Weekly values of precipitation quality at Noatun, Svanvik and Karpdalen for the periods, when concentration of Cl > 5 mg/l.

	Amount	Conductivity	pH	SO_4	Cl	Mg	NO_3	NH_4	Ca	K	Na
Week	mm	µS/cm		mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
Noatun											
1.-5.11.	5.3	58	6.42	3.7	7.9	0.73	3.8	0.9	3.4	2.6	5.0
12.-19.11.	1.6	54	4.98	3.8	10.0	0.50	3.2	1.1	1.0	2.1	5.2
29.1-1.2.	0.6	73	5.42	5.7	15.8		4.9			0.2	0.7
Svanvik											
12.-19.11.	2.7	44	4.27	2.1	5.9	0.38	2.7	0.2	0.3	0.1	3.2
Karpdalen											
7.1.-14.1.	1.0	99	4.08	5.5	15.4	1.17	4.5	0.3	0.5	0.4	8.6
25.2.-1.3.	0.7	83	4.05	4.8	17.2	1.01	0.8		0.4	0.6	8.9
25.3.-1.4.	15.6	42	4.39	3.3	7.0	0.56	0.3	<0.1	0.2	0.2	3.9
1.5.-6.5	1.1	114	3.45	14.1	12.8	0.57	3.4	1.2	0.7	0.6	8.0
27.5.-1.6.	1.1	249	3.92	20.0	49.6	3.60	3.9	0.6	1.9	1.4	28.1

indicating that sea-salt particles are the dominating source for chloride in precipitation.

The concentration of NO_3^-, was generally low, and increased insignificantly with increasing concentration of sulphate.

6.5 ANALYSIS OF CORROSION DATA

The results of the corrosion tests are presented in Tables 9a and 10a. Table 5 shows the monthly mass losses of steel added to three months' and one year's corrosion results for comparison of the total mass losses during three months' and one year's periods. One may see, that the total of the monthly mass losses of steel for 12 months for all test sites were higher than that for a year's period of continuous tests. The total of the three months' mass losses of steel for 4 three months' period is also higher for all the test sites than the mass losses of steel for a year's period of tests. However, the sum or the monthly mass losses for 3 months' periods ($M_1+M_2+M_3$) compared to the mass losses of steel for three months' tests (M_{1-3}) were in 50% of the cases are lower than the continuous tests during the same periods. An analogous regularity in 60% of the cases was observed during one month's and three months' tests of steel carried out earlier by Norway in the same area showed in ref. 6. In a number of other cases at medium and low corrosion rates an approximate equality of the sums of the monthly mass losses of steel and the mass losses during three months' continuous tests was observed.

The analysis of Tables 5 and 6 shows that:

- In most cases no regularity was observed on sites with high corrosion rates (Sov2, Viksjøfjell) except for the observation that $M_1+M_2+M_3 > M_{1-3}$;
- During the periods, when $(M_1+M_2+M_3) < M_{1-3}$, at low values of mass losses M, the ratio $(M_1+M_2+M_3)/M_{1-3}$ is, as a rule, much lower than one, and in some cases, it may be below 0.5.

Table 5: A comparison of the corrosion mass losses of the steel during 3 months' corrosion tests and total corrosion mass losses for 3 months' during monthly tests, during yearly tests and total mass losses for 1 year during monthly tests, during yearly tests and total mass losses during 3 months' tests (mass loss in g/m^2).

Period	Viksjøfjell	Karpdalen	Svanvik	Kobbfoss	Noatun	Sov1	Sov2	Sov3
6/90+7/90+8/90	122.0	57.7	27.1	34.4	27.4	34.2	120.0	54.0
6/90 - 8/90	108.0	66.0	40.1	44.0	37.0	29.0	90.0	63.0
9/90+10/90+11/90	152.0	83.0	36.4	33.6	30.5	21.3	-	-
9/90 - 11/90	143.0	21.0	42.0	36.0	32.0	19.0	-	
12/90+1/91+2/91	112.0	55.6	23.7	21.0	30.6	31.0*	-	-
12/90 - 2/91	98.0	46.0	19.0	16.0	21.0	38.0	-	-
3/91+4/91+5/91	84.0	43.9	21.5	14.4	10.6	-	-	-
3/91 - 5/91	97.0	54.0	39.0	31.0	20.0	-	-	-
Sum monthly values								
6/90+7/90+**+5/91	470.0	240.2	108.7	103.4	99.1	-	-	-
6/90 - 5/91	308.0	180.0	108.0	91.0	78.0	-	-	-
Sum 3 month's values								
6-8/90+**+3-5/91	446.0	187.0	140.0	127.0	110.0	99.0	-	-
6/90-5/91	308.0	180.0	108.0	91.0	78.0	93.0	-	-

(*) (12/90 ÷ 1/91) + 2/91

The results obtained are in agreement with the model considered in Chapter 5. During three months' tests which cover a large part of section II, the corrosion process will include the highest corrosion rate and the mass losses become higher than the sum of monthly losses. During a yearly exposure period partial protective corrosion products will cover the surface (section III of curve 2, Figure 2), as a result the mass losses during continuous yearly tests are lower than the total of monthly or three months' mass losses for one year's period.

Thus, the results obtained point to the presence of the SO_2 level, at which the air-oxide film on the steel surface is destroyed and the corrosion rate (V) increases abruptly (dV/dt >0), Figure 4. This evidently also occurs at sites with low concentrations of SO_2.

Table 6: A comparison of the corrosion mass losses of steel during 3 months corrosion tests and total corrosion mass losses for 3 months during monthly tests at the sites in Norway (mass loss in g/m²).

Period	Viksjøfjell	Karpdalen	Svanvik	Kobbfoss	Noatun
10/88+11/88+12/88 10/88 - 12/88	163.0 134.7	57.3 51.0	17.0 13.0	13.3 12.3	13.3 12.7
1/89+2/89+3/89 1/89 - 3/89	150.3 156.0	61.3 77.7	27.0 28.0	18.3 18.3	23.7 19.7
4/89+5/89+6/89 4/89 - 6/89	132.7 122.3	75.3 73.3	61.7 58.0	59.3 50.3	39.3 29.7
7/89+8/89+9/89 7/89 - 9/89	202.7 153.7	75.0 82.1	55.0 65.4	41.0 43.0	15.9 38.0
10/89+11/89+12/89 10/89 - 12/89	139.2 130.7	60.8 72.8	17.4 29.3	6.8 17.3	9.3 19.7
1/90+2/90+3/90 1/90 - 3/90	88.7 116.1	45.7 69.1	18.8 40.5	18.6 30.9	16.0 25.9
4/90+5/90+6/90 4/90 - 6/90	92.1 108.1	34.1 56.7	13.2 31.3	16.8 38.3	11.8 22.6

It is noteworthy that model curve 2, Figure 2 assumes the SO_2 level to be constant during the whole test period, while in real atmospheric tests the SO_2 level may vary over a wide range. This circumstance is obvious and one of the reasons why the above trend is not observed in all the cases.

Table 7 shows the results of the linear regression analysis of the mass losses of materials as a function the average SO_2 levels during the same monthly and yearly test periods (monthly linear regression was not carried out on data from November to April because of too few corrosion data available). The number of observations in the tables corresponds to the number of test sites. In all these cases the coefficients of correlation obtained were rather high (except for monthly steel in June 1990 with R=0.083).

Some discrepancies in the mass losses of steel and the monthly average SO_2 levels were observed for the sites in Kobbfoss and Svanvik in July 1990. During short-term tests, when the SO_2 level varied significantly, the correlation between mass losses and the average SO_2 levels was reduced. This is caused by differences in the presence of pollutants and on the amount of wet deposition, TOW > 80%. Figure 8 shows, as an example, the variations of the SO_2 concentrations in July in Svanvik and Viksjøfjell, for which the monthly average SO_2 values were equal to 12 and 11 $\mu g/m^3$, respectively, and the corrosion losses 11 and 39 g/m^2 (Viksjøfjellet had the high SO_2 concentration the first days of the month and Svanvik during the last ones). However, the difference in the corrosion rates at Svanvik and Noatun, where the kinetics of the change in SO_2 was analogous in July 1990, are difficult to be accounted for by this fact. A possiblility may be the difference in the wet and dry deposition of SO_2. This may be analysed from the TOW data for this period. The monthly average SO_2 values in Kobbfoss in 7/90 was based on incomplete data, which might have affected the accuracy of the results. If these points are not taken into account the correlation coefficient for July is above 0.9, Table 7.

A systematic high corrosion mass loss compared to the average SO_2 levels was observed at Viksjøfjell during the yearly tests, as well as during monthly tests in June and September 1990 and three months' tests from 6.90 to 8.90 (we failed to obtain monthly corrosion data in Sov2 from 11.90 to 1.91 and from 3.91 to 5.91 and three months' tests during 9.90 to 5.91). In Table 8 the test sites are arranged in decreasing order according to the yearly average SO_2 levels and corrosion mass losses of steel and zinc. Despite the fact that the SO_2 levels at Sov2 and Sov3 were higher than those at Viksjøfjell, the corrosion losses at Viksjøfjell were much higher, which points to the presence of other corrosion-active factors.

Table 7: The values of the coefficients (A_1, A_2) coefficient of correlation R and F-Ratio for the regression equation of mass loss (M, g/m^2) vs. the average concentration of sulphur dioxide (SO_2, $\mu g/m^3$) in the atmosphere of test sites ($M = A_1 + A_2 \cdot (SO_2)$).

Steel

Period	Number of observations	A_1	A_2	R	F
1 month Steel					
7/90	6*	-36.690	7.310	0.964	52.89
8/90	8	1.403	1.282	0.975	116.36
9/90	8	3.485	1.283	0.921	33.38
10/90	6**	7.553	0.973	0.968	57.20
5/91	4	-5.555	2.510	0.914	10.20
1 year Steel					
6/90-5/91	6**	68.197	3.496	0.968	20.62
1 year Zinc					
6/90-5/91	6**	5.061	0.247	0.972	67.46
1 year Galvanized Steel					
6/90-5/91	6**	1.985	0.235	0.987	149.46
1 year Aluzinc					
6/90-5/91	6**	1.034	0.149	0.978	88.51
1 year Helix Aluminium					
6/90-5/91	6**	-0.277	0.044	0.958	45.02
1 year Helix galvanized Steel					
6/90-5/91	6**	0.610	0.043	0.981	102.85
1 year Helix "Galfan-steel"					
6/90-5/91	6**	0.175	0.044	0.980	98.24

*) Without taking into account the data in Svanvik and Kobbfoss.
**) In Viksjøfjell and Kobbfoss.

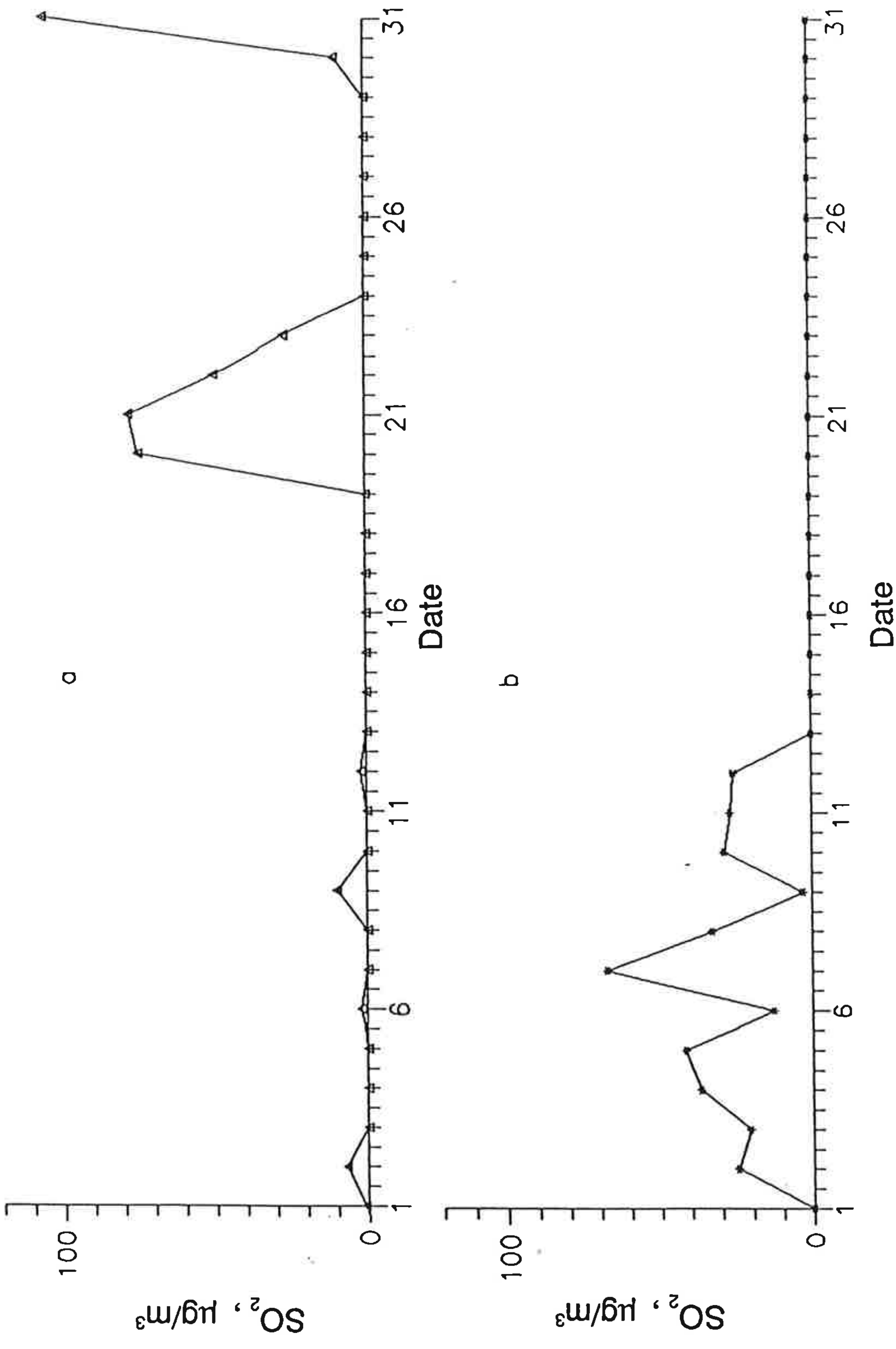

Figure 8: The SO_2 concentration levels ($\mu g/m^3$) in July 1990 for Svanvik (a) and Viksjøfjell (b).

Table 8: Test sites arranged in descending order according to the yearly average SO_2 levels and corrosion mass losses of steel and zinc for the period June 1990-May 199.

SO_2, µg/m^3

Sov2 →	Sov3 →	Viksjøfjell →	Karpdalen →	Svanvik →	Sov1 →	Noatun
56.9	43.1	37.1	21.3	13.0	9.9	5.9

Steel weight loss, g/m^2

Viksjøfjell →	Sov2 →	Sov3 →	Karpdalen →	Svanvik →	Sov1 →	Noatun
308	261	214	180	108	93	78

Zinc weight loss, g/m^2

Viksjøfjell →	Sov2 →	Sov3 →	Karpdalen →	Svanvik →	Sov1 →	Noatun
24	19	15	12	9.6	6.4	5.

Dry deposition of Cl is likely to be a corrosion-active factor affecting the yearly average value of mass losses at Viksjø-fjell and partially at Karpdalen. The values of dry deposition of Cl at Viksjøfjell recorded from November 1990 to March 1991 approximately correspond to those on the Black Sea coast.

At present it is difficult to give the answer to the question, to what extent the differences in TOW may affect corrosion at Viksjøfjell. The analysis of the TOW values (at T >0 and Rh >80%) and corrosion losses during monthly tests from 10.90 to 5.91 shows their obvious disagreement. The corrosion mass losses take place even in periods, when the maximum temperature values are negative. Since this effect was observed earlier during atmospheric corrosion investigations in the USSR, the National Standard of the USSR GOST 9.039-74 "Corrosive aggressiveness of atmosphere" (7) developed by the Institute of Physical Chemistry, takes into account the possibility of the development of atmospheric corrosion at T > -1° C. However, the experimental results obtained lead us to believe that the existence of electrolyte films in a humid atmosphere and the development of corrosion processes in metals take place even at lower temperatures. An earlier investigation in a copper mining town, Sulitjelma, Norway, indicated a temperature limit for steel between -2° and -4° C and for zinc corrosion even lower (8). In the subarctic climate with a very short summer, when temperatures below 0° C are recorded 9-10 months a year, an adequate account of the temperature factor while determining the TOW is of particulare importance. Therefore the development of a model, describing the dependence of the mass losses on climatic parameters and SO_2 pollutant for the whole test period, as well as the evaluation of the critical temperature values to determine the TOW, is possible. The model will be based on the statistical analysis of the results obtained and on the sets of monthly TOW values at Rh >80% and at several negative temperatures, determined from continuous or 8 times/day temperature and relative humidity measurements. It is evident that the difference in TOW values due to the temperature factor, will be negligible in the tropical and subtropical climate, and insignificant in the moderate climate. At present for the subarctic climate the corrosive aggressiveness is underrated due to the inaccurate determination of the TOW.

On the whole, the correlation of mass losses of materials and SO_2 levels for different time periods was good. Therefore, in addition to specific evaluations of the pollutant effect on materials we should note the possibility of atmospheric corrosion tests as an instrument for long term monitoring purposes.

From Table 7 it follows that during the exposure of steel in July 1990 and in May 1991 and aluminium (1 year) the constant A_1 term of the linear regression equation has the negative sign. However, the values of the correlation coefficient is close to 1, which point to a high reliability of the data obtained. Since the mass losses of steel cannot be negative and corrosion takes place even at SO_2=0, it would be reasonal to expect the presence of the break point of the curve for mass losses vs. the SO_2 level in terms of the model suggested in Figure 4. In that case, the experimental data obtained (Figures 9 and 10) describe phase II of the curves in Figure 2. The region of the monthly average SO_2 levels, in which the

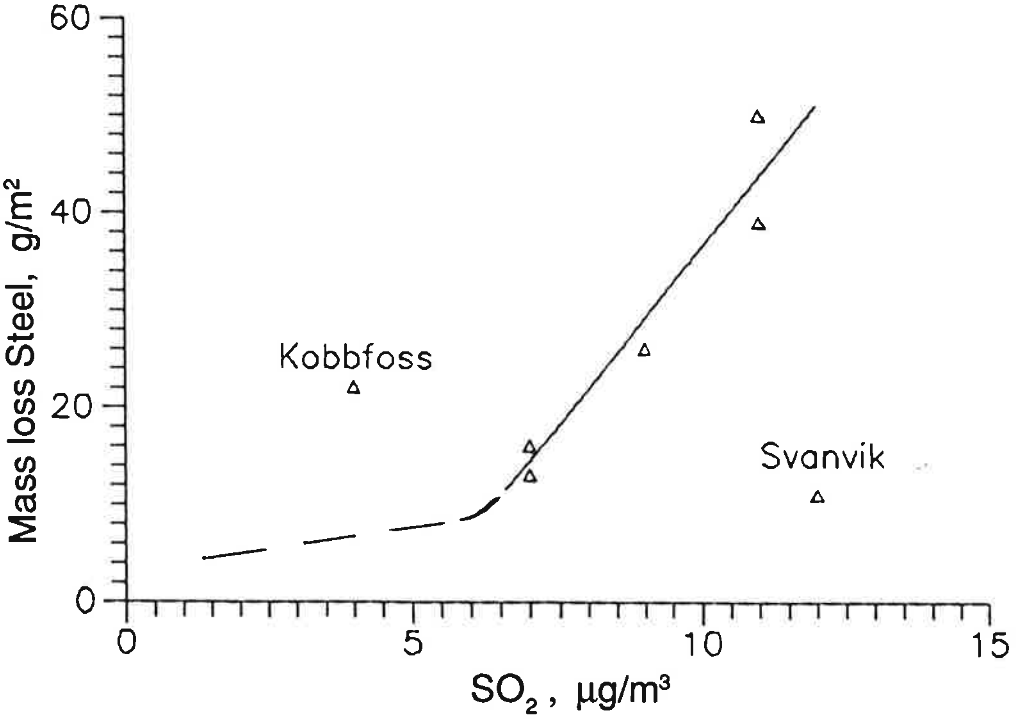

Figure 9: Mass loss of steel in July 1990 vs. concentration of SO_2 in air. The best fitted line is drawn without taking into account the data in Svanvik and Kobbfoss.

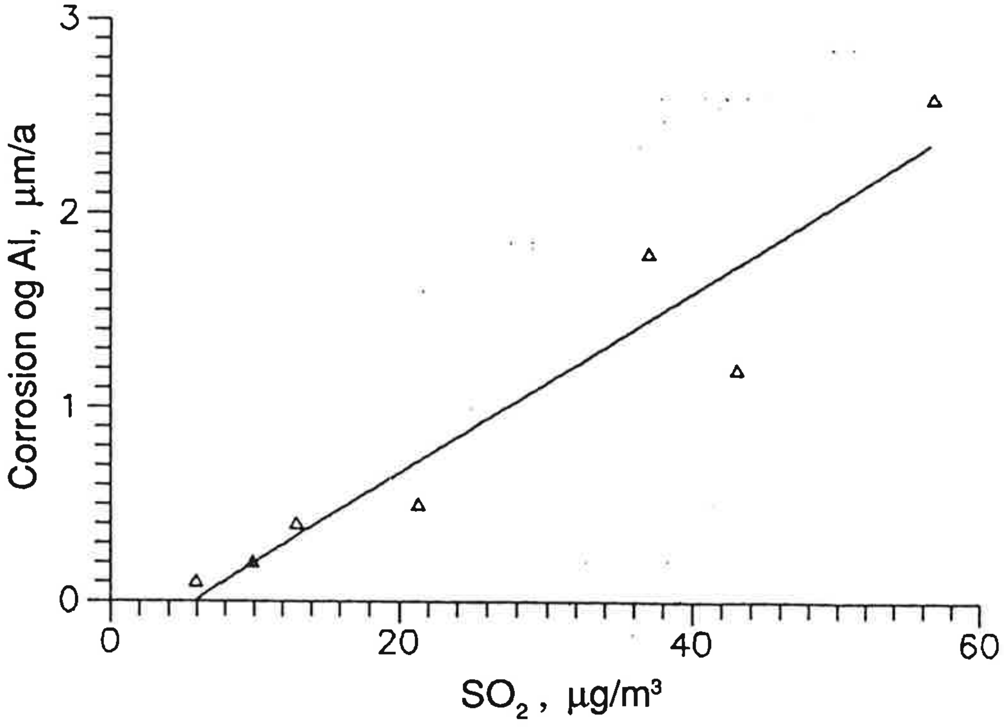

Figure 10: Corrosion of Al for 1 year exposure vs. concentration of SO_2 in air.

break of the curve takes place, lies below 10 μg/m³ (supposedly from 5 to 10 μg/m³) for aluminium from 5 to 10 μg/m³.

The result obtained leads us to believe that the limiting target level for materials may be below the critical levels suggested for biological objects (forests, natural vegetation - 20 μg/m³, crops - 30 μg/m³ /1/). Obviously each material has its own optimum test period, which allows the recording of the limiting target level or the range of SO_2 levels, in which it lies.

Taking into account the TOW data and the above-mentioned possibility of corrosion at negative temperatures we can conclude that the data for August and September, 1990 are valid (the TOW at Viksjøfjell in June and July are not recorded). Table 9 shows the calculated constants of equations 1-4 for August, September and August and September 1990 taken together. Equation 2 increases the correlation coefficient also in August (8.90) and September (9.90), however, the negative coefficients at TOW is not in agreement with the physico-chemical mechanisms of atmospheric corrosion. Equation 3 looks more reasonable, however, it should be noted that this equation is also applicable to the range of SO_2 levels above the limiting target level. When equation 4 is used, the coefficients A_3 and A_4 differ insignificantly from 1.

Different from the one year Al-corrosion results, the steel corrosion results split in two groups (Figure 11). Sov2 and Sov3 show a different behaviour compared to Viksjøfjellet and Karpdalen. A possible explanation could be that chloride plays a more dominating part at these two Norwegian sites compared to the Russian sites. However, this indicates that chloride from other sources than Nickel, like sea-salt aerosols, must be considered. This can only be proved if chloride can be measured also on the Russian sites.

$$\text{Mass Loss } (g/m^2) = A_1 + A_2 * C_{SO_2} \ (\mu g/m^3) \qquad (1)$$

$$\text{Mass Loss } (g/m^2) = A_1 + A_2 * C_{SO_2} \ (\mu g/m^3) + A_3 * TOW \ (h) \qquad (2)$$

$$\text{Mass Loss } (g/m^2) = (A_1 + A_2 * C_{SO_2} \ (\mu g/m^3)) * TOW \ (h) \qquad (3)$$

$$\text{Mass Loss } (g/m^2) = \left[A_1 + A_2 * (C_{SO_2} \ (\mu g/m^3))^{A_3}\right] * ((TOW) \ (h))^{A_4} \qquad (4)$$

Table 9:

Period		A_1	A_2	A_3	A_4	R-sq.
8/90	1	1.403	1.282	-	-	0.951
8/90	2	42.084	1.194	-0.110	-	0.984
8/90	3	0.00540	0.00352	-	-	0.855
9/90	1	3.485	1.283	-	-	0.848
9/90	2	-52.272	1.128	0.160	-	0.919
9/90	3	0.00627	0.00354	-	-	0.935
9/90	4	0.0000386	0.0009357	0.922	1.279	0.947
8/90+9/90	2	- 9.833	1.280	0.034	-	0.897
8/90+9/90	3	0.00571	0.00354	-	-	0.899

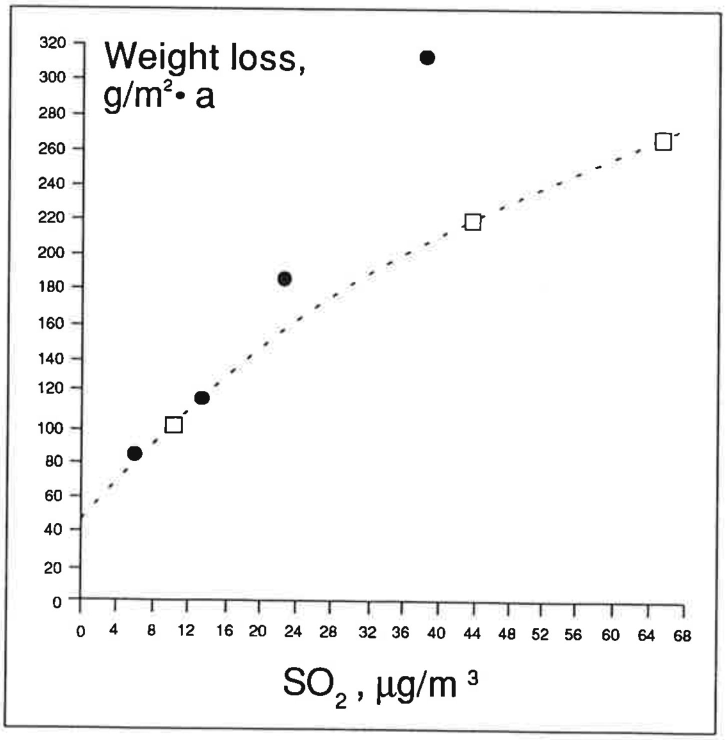

Figure 11: Yearly corrosion rate for carbon steel vs. the yearly mean concentrations of sulphur dioxide.
● Norwegian sites
□ Russian sites

The results obtained allow us to propose the following plan for further analysis of the results:

- To obtain TOW data sets for different temperatures, relative humidity scenarios TOW > 80% or higher, temperature T > 0 or lower;

- To make a statistical evaluation of the results of monthly and three months' tests for different sites, using the TOW values and the temperature, at which corrosion processes may develop in the subarctic climate. To study a possible effect of dry deposition of Cl for the sites, where they were measured;

- To make a statistical evaluation of the possibility to derive a universal equation for the description of all the corrosion data obtained using meteorological data and SO_2 data.

7 CONCLUSION

The results of the corrosion tests of metal materials show that also in the subarctic climate the metal corrosion is dependent of the atmospheric pollution level of antropogenic nature. The physico-chemical models describing corrosion in different climatic regions of the world are in general applicable to subarctic regions. Because of the temperature range found in the subarctic, the importance of defining the real time of wetness on the surface will increase. The general rule $T > 0^o$ and Rh > 80% which works well in a moderate climate, must probably be more refined in subarctic areas.

The high sensitivity of metal corrosion to the level of pollutants in the air allows one to construct a model, which determines the limiting target SO_2 level and which may even be used for ecological monitoring.

From the analysis of the results obtained we may draw the following conclusions:

1. The temperature-wetness characteristics of different sites and the amount of atmospheric precipitation on them differed insignificantly;

2. The prevailing wind directions as measured at the Norwegian test sites, Viksjøfjell 210-240° and Svanvik 180-240°, lead to the transfer of the sulphur pollutants from Nickel and Zapolyarny and increased metal corrosion at sites Sov2, Sov3, Viksjøfjell and Karpdalen.

3. Dry deposition of Cl increases in the order Viksjøfjell > Karpdalen > Svanvik and at Viksjøfjell it becomes comparable to dry deposition of Cl on the Black Sea coast. The Cl/Mg ratio measured also indicates that sea-salt aerosols are an important Cl source. In the period 11/90 to 3/91 dry deposition of Cl may make its own contribution to the processes of atmospheric corrosion at Viksjøfjell and partially at Karpdalen. There is good correlation between dry deposition of Cl in Viksjøfjell and the time of the wind >6 m/s for the wind direction 240° ($R = 0.619$), while in Svanvik and Karpdalen the changes in dry deposition of Cl are negligible. The sources for Cl must be investigated in more detail.

4. The precipitation is characterized by increasing acidity and sulphate concentration when moving from the south to the north in the area. The concentration of Cl, Na and Mg are corresponding to the ratios found in sea-salt aerosols.

5. The disagreement between the corrosion mass losses and the TOW values in the period 10/90 to 5/91 points to the possibility of the existence of electrolyte films on metals and an active corrosion process at negative temperatures. Therefore, it is necessary to evaluate the limits used in the international standards for the determination of TOW.

6. The corrosion losses on the test sites during simultaneous tests for equal time periods depend mainly on the average SO_2 for the test period. The corrosion rate at Viksjøfjell is higher than expected compared to the rest of the test sites. To obtain an equation which describes the dependence of the mass losses for any time period it is necessary to take into account the time of wetness with a possible development of corrosion processes at negative temperatures.

The Norwegian Institute for Air Research and the Institute of Physical Chemistry of the Russian Academy of Sciences will recommend to include the research of the effect of sulphur pollutants on atmospheric corrosion of materials in the given region in the bilateral scientific research programme in terms of the current agreement on co-operation in the environmental field between Norway and Russian Federation, with the necessary financial support by both countries.

In addition to study the mechanism of the corrosion effect in a subarctic area, we will propose to study the possibility of setting up a series of small cheap test sites using corrosion of steel as a sensor for the sulphur load in different parts of the area.

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APPENDIX A

Table A1: Monthly temperature results for the period April 1990-May 1991.

	Viksjøfjell			Svanvik			Noatun		
	Mean	Max	Min.	Mean	Max	Min.	Mean	Max.	Min.
Apr 1990	-1.7	8.9	-13.8	0.9	14.2	-21.8	0.9	13.8	-21.1
May 1990	-0.5	14.0	-6.4	3.3	20.0	-4.2	3.8	18.8	-3.8
Jun 1990	6.0	24.5	-1.0	11.1	31.3	-1.5	10.3	27.3	2.0
Jul 1990	9.8	19.3	2.8	12.4	26.1	3.5	13.5	22.5	5.4
Aug 1990	9.6	21.2	2.3	11.2	22.5	-0.2	12.6	23.0	0.5
Sep 1990	4.1	14.4	-0.9	6.3	21.4	-2.8	6.3	17.1	-2.4
Oct 1990	-1.6	6.1	-8.8	-0.1	7.1	-6.9	0.8	8.9	-8.0
Nov 1990	-7.7	0.5	-17.8	-11.4	-0.7	-23.7	-7.7	2.4	-24.5
Dec 1990	-	-	-	-8.1	2.1	-20.2	-5.3	5.4	-25.0
Jan 1991	-6.7*	1.9*	-18.2*	-14.2	0.8	-32.5	-11.6	4.7	-34.6
Feb 1991	-9.3	-1.1	-19.8	-13.4	-0.5	-28.6	-13.0	2.3	-34.0
Mar 1991	-9.6	1.4	-16.7	-12.8	0.2	-27.5	-10.2	4.8	-30.6
Apr 1991	2.2	5.5	-15.1	-2.7	5.4	-29.4	-0.2	9.0	-31.5
May 1991	0.6	10.2	-10.6	2.9	14.7	-11.7	3.9	14.8	-10.0

* Date from 1-15 January missing values.

Table A2: Monthly mean relative humidity results for the period June 1990-May 1991 at Svanvik, Noatun and Viksjøfjell.

Month	Svanvik	Noatun	Viksjøfjell
Jun 1990	69	64	-
Jul 1990	76	77	-
Aug 1990	77	77	74
Sep 1990	78	81	82
Oct 1990	81	84	91
Nov 1990	86	85	92
Dec 1990	85	84	-
Jan 1991	84	78	-
Feb 1991	83	86	88
Mar 1991	80	77	87
Apr 1991	71	67	70
May 1991	65	66	68

Table A3: Time of wetness.
TOW >80%.

Station	Month	TOW T> 0°	TOW T> -2°	TOW T> -4°	TOW T> -6°
Viksjøfjell	6/90	-	-	-	-
	7/90	-	-	-	-
	8/90	306	306	306	306
	9/90	423	454	454	454
	10/90	145	353	515	589
	11/90	5	50	137	190
	12/90	-	-	-	-
	1/91	-	-	-	-
	2/91	0	19	62	108
	3/91	0	18	47	81
	4/91	107	135	162	183
	5/91	43	66	88	93
Svanvik	6/90	266	268	268	268
	7/90	394	394	394	394
	8/90	386	389	389	389
	9/90	335	381	391	391
	10/90	188	312	393	423
	11/90	0	29	81	112
	12/90	1	12	97	127
	1/91	1	11	21	26
	2/91	0	15	46	69
	3/91	0	0	3	30
	4/91	51	134	162	221
	5/91	130	156	172	198

Table A4: Monthly average of daily or continuous SO_2-measurements.

Station	Month	Mean	Highest daily value	No. of observ.	No. of days with mean > 50	No. of days with mean >100	Highest hourly value
Viksjøfjell	Jun 1990	12	63	30	1	0	469
	Jul	11	68	31	1	0	281
	Aug	38	123	31	9	1	803
	Sep	37	188	30	9	4	899
	Oct	25	122	31	4	2	962
	Nov	26	186	30	7	2	926
	Dec	47	231	31	9	4	1 038
	Jan 1991	66	406	31	10	7	1 697
	Feb	49	526	28	8	3	1 047
	Mar	82	570	31	12	6	1 975
	Apr	39	128	30	12	2	717
	May	13	50	31	2		309
Svanvik	Jun 1990	12	68	30	4	0	777
	Jul	12	106	31	3	1	532
	Aug	11	68	31	3	0	1 170
	Sep	9	96	30	1	0	395
	Oct	5	38	31	0	0	216
	Nov	11	125	30	2	1	805
	Dec	11	84	31	2	0	434
	Jan 1991	18	92	31	5	0	251
	Feb	11	98	28	2	0	159
	Mar	40	608	31	6	2	1 060
	Apr	8	144	30	1	1	718
	May	8	50	31	1	0	351
Noatun	Jun 1990	7	61	24	1	0	
	Jul	7	51	31	1	0	
	Aug	3	14	31	0	0	
	Sep	4	35	30	0	0	
	Oct	2	19	31	0	0	
	Nov	2	23	22	0	0	
	Dec	14	149	18	2	1	
	Jan 1991	11	58	30	1	0	
	Feb	7	48	26	0	0	
	Mar	9	46	31	0	0	
	Apr	2	19	25	0	0	
	May	3	20	31	0	0	
Karpdalen	Jun 1990	5	41	30	0	0	250
	Jul	7	48	31	0	0	251
	Aug	25	133	31	6	1	1 057
	Sep	22	108	30	6	1	449
	Oct	21	119	31	6	1	1 333
	Nov	12	75	30	4	0	388
	Dec	27	115	31	7	1	940
	Jan 1991	44	293	31	9	3	532
	Feb	20	160	28	4	3	368
	Mar	45	356	17	3	3	756
	Apr	19	114	30	3	1	
	May	8	74	31	1	0	
Kobbfoss	Jun	14	122	27	3	1	
	Jul	4	40	14			
	Aug	5	63	27	1		
	Sep	5	41	30			
	Oct						
	Nov	measurements stopped from October 1990					
	Dec						
	Jan 1991						
	Feb						
	Mar						
	Apr						
	May						

Table A4, SO_2 cont. (monitor)

Station	Month	Mean	Highest daily value	No. of observ.	No. of days with mean	
					>50	>100
Sov 1	Jun 1990	13	83	30	2	
	Jul	9	81	31	2	
	Aug	4	17	7		
	Sep	4	35	13		
	Oct	3	19	31		
	Nov	15	96	30	2	
	Dec	14	57	31	2	
	Jan 1991	12	52	31	2	
	Feb	11	56	28	1	
	Mar	20	157	31	4	1
	Apr	8	77	30	1	
	May	6	37	31		
Sov 2	Jun 1990	18	116	30	6	1
	Jul	11	91	29	2	
	Aug	51	161	31	14	6
	Sep	53	220	30	14	5
	Oct	58	348	31	10	7
	Nov	57	418	17	6	2
	Dec	-	-	-		
	Jan 1991	-	-	-		
	Feb	118	612	24	11	9
	Mar	124	571	31	20	16
	Apr	67	320	30	13	6
	May	12	85	31	2	
Sov 3	Jun 1990	9	60	30	1	
	Jul	7	27	18	-	
	Aug	16	90	31	3	
	Sep	26	167	30	6	2
	Oct	32	152	31	7	3
	Nov	65	267	26	11	8
	Dec	65	239	31	14	7
	Jan 1991	45	190	31	13	5
	Feb	85	292	28	17	9
	Mar	89	304	31	18	11
	Apr	65	466	30	13	6
	May	13	85	31	4	

Tabell A5: Dry deposition with NILUs aerosol trap.

Station	Period	Cl µg/m²d	Mg µg/m²d	Cl/Mg
Viksjøfjell	01.06.90 - 01.07.90	1457.8	84.4	17.3
	01.07.90 - 02.08.90	229.2	16.7	13.7
	02.08.90 - 31.08.90	1328.7	156.3	8.5
	31.08.90 - 01.10.90	735.5	34.4	21.3
	01.10.90 - 03.11.90	1519.2	80.8	18.8
	03.11.90 - 01.12.90	5585.7	328.6	17.0
	01.12.90 - 02.01.91	7754.2	454.2	17.1
	02.01.91 - 01.02.91	5933.3	328.9	18.0
	01.02.91 - 01.03.91	3373.1	145.1	23.2
	01.03.91 - 01.04.91	4477.4	197.9	22.6
	01.04.91 - 01.05.91	1808.9	57.8	31.3
Karpdalen	03.06.90 - 01.07.90	704.8	23.8	29.6
	01.07.90 - 01.08.90	1944.1	64.5	30.1
	01.08.90 - 01.09.90	1333.3	116.1	11.5
	01.09.90 - 01.10.90	1004.4	35.6	28.3
	01.10.90 - 01.11.90	1273.1	81.7	15.6
	01.11.90 - 01.12.90	1435.6	71.1	21.2
	01.12.90 - 01.01.91	1458.1	55.9	26.1
	10.01.91 - 01.02.91	1412.1	90.9	15.5
	01.02.91 - 01.03.91	1171.4	54.4	21.5
	01.03.91 - 01.04.91	1281.7	73.1	17.5
	01.04.91 - 01.05.91	1142.2	40.0	28.6
Svanvik	04.06.90 - 29.06.90	874.7	26.7	32.8
	29.06.90 - 01.08.90	830.2	20.2	41.1
	01.08.90 - 01.09.90	774.2	47.3	16.4
	01.09.90 - 01.10.90	1026.7	53.3	19.3
	01.10.90 - 01.11.90	907.5	43.0	21.1
	01.11.90 - 01.12.90	693.3	26.7	26.0
	01.12.90 - 03.01.90	888.9	24.2	37.0
	03.01.90 - 01.02.91	777.0	41.4	18.8
	01.02.91 - 01.03.91	915.6	43.5	21.0
	01.03.91 - 01.04.91	434.4	17.2	25.6
	01.04.91 - 01.05.91	351.1	missing	
	01.05.91 - 01.06.91			

Tabell A6: Weekly values of precipitation quality at Svanvik.

	Amount of precipitation	Conductivity	pH	SO_4	Cl	Mg	NO_3	NH_4	Ca	K	Na
Week	mm			mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
1. - 4.6.	4.0	12	4.70	1.7	0.5	0.07	0.3	<0.1	0.1	<0.1	0.3
4. - 11.6.	1.6	23	4.63	3.4	2.3	0.30	0.7	0.1	0.5	0.1	1.2
11. - 18.6.	16.5	12	4.95	0.9	1.7	0.12	0.3	<0.1	0.1	<0.1	0.8
18. - 25.6.	0.0										
25.6 - 1.7.	0.5	43	4.25								
1. - 2.7.	0.1										
2. - 9.7.	3.2	18	4.64	2.1	0.2	0.12	0.8	<0.1	0.5	0.2	<0.1
9. - 16.7.	6.2	26	4.47	2.8	2.0	0.17	0.9	0.2	0.2	0.1	1.1
16.7. 23.7.	8.0	16	4.50	0.8	0.3	0.03	1.1	<0.1	<0.1	<0.1	0.2
23. - 30.7.	4.8	16	4.69	1.9	0.7	0.09	0.9	0.4	0.2	<0.1	0.4
30.7.- 1.8.	0.0										
1. - 6.8.	42.7	22	4.28	2.4	0.2	0.02	0.4	<0.1	<0.1	<0.1	0.1
6. - 13.8.	7.6	9	5.02	0.7	0.7	0.06	0.2	0.1	<0.1	<0.1	0.4
13. - 20.8.	8.0	19	4.39	2.3	<0.1	0.03	0.8	0.3	<0.1	<0.1	<0.1
20. - 27.8.	1.9	49	4.10	6.2	1.4	0.18	1.1	0.3	0.4	0.1	0.7
27.8 - 1.9.	1.2	48	3.96	7.6	0.9	0.15	0.7	0.1	0.2	<0.1	0.5
1.3 - 3.9.	0.0										
3. - 10.9.	0.0										

Table A6, cont.

	Amount of preci-pitation	Conduc-tivity	pH	SO_4	Cl	Mg	NO_3	NH_4	Ca	K	Na
Week	mm			mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
10. - 17.9.	4.1	7	5.04	1.1	<0.1	0.03	0.2	0.1	<0.1	<0.1	<0.1
17.9. 24.9.	3.6	20	4.67	2.5	1.9	0.18	0.4	0.3	0.2	<0.1	1.0
24.9. 1.10.	6.8	17	4.87	1.0	2.4	0.17	0.2	<0.1	<0.1	<0.1	1.3
1. - 8.10.	1.5	13	4.95								
8. - 15.10.	2.8	30									
15. - 22.10.	4.5	148	4.65	1.9		0.12	0.7	0.2	0.1		0.7
22. - 29.10.	0.8	27									
29.10- 1.11.	0.2	6									
1. - 5.11.	2.2	18	4.50								
5. - 12.11.	5.5	19	5.38	1.0	3.9	0.22	0.4	0.3	0.2	0.5	2.2
12. - 19.11.	2.7	44	4.27	2.1	5.9	0.38	2.7	0.2	0.3	0.1	3.2
19. - 26.11.	5.4	14	4.95	0.9	2.1	0.13	0.3	0.2	<0.1	<0.1	1.0
26.11. 1.12.	5.4	18	4.98	0.9	3.7	0.23	0.4	<0.1	<0.1	<0.1	2.0
1.0 - 3.12.	4.8	13	4.89	0.7	2.1	0.14	0.2	<0.1	<0.1	<0.1	1.0
3. - 10.12.	0.6	129	3.87								
10 - 17.12.	0.6	82									
17.- 24.12.	14.6	14	4.60	0.8	0.9	0.08	0.8	<0.1	<0.1	<0.1	0.4
24. - 31.12	0.4	129	3.88								

Table A6, cont.

Week	Amount of precipitation mm	Conductivity µS/cm	pH	SO_4 mg/l	Cl mg/l	Mg mg/l	NO_3 mg/l	NH_4 mg/l	Ca mg/l	K mg/l	Na mg/l
31.12-1.1.	0.0										
1. - 7.1.	0.0										
7.1 - 14.1.	1.4	47	4.17	4.0	2.7	0.32	5.8	0.8	0.4	0.1	1.5
14. - 21.1.	0.2										
21.1.-28.1.	15.0	10	4.94	0.8	1.3	0.11	0.3	<0.1	<0.1	<0.1	0.7
28.1. 1.2.	1.1	30	4.50	2.3	3.3	0.26	1.4	0.3	0.2	<0.1	1.8
01. - 4.2.	0.0										
4.2. - 11.2.	0.0										
11.2 - 18.2.	0.3	46	4.36								
18. - 25.2.	3.3	38	4.20	3.3	1.6	0.17	3.1	0.4	0.3	0.2	0.7
25.2. 1.3.	0.0										
1. - 4.3.	0.2	29									
4.3. - 11.3.	10.5	16	4.60	1.4	0.6	0.06	1.0	0.2	0.1	<0.1	0.3
11.3. 18.3.	1.6	28	4.61	3.4	2.4	0.27	1.0	0.4	0.5	0.1	1.4
18.3 - 25.3.	0.0										
25.3 - 1.4.	8.9	25	4.91	1.1	4.8	0.40	0.4	0.1	0.2	0.1	2.9
1.4. - 8.4.	0.0										
8.4. - 15.4.	0.0										

Table A6, cont.

	Amount of preci-pitation	Conduc-tivity	pH	SO_4	Cl	Mg	NO_3	NH_4	Ca	K	Na
Week	mm	µS/cm		mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
22.4.-29.4.	0.0										
29.4 - 1.5.	0.0										
1.5. - 6.5.	2.8	42	4.34	4.9	2.8	0.23	2.0	0.8	0.4	0.3	1.6
6.5. - 13.5.	0.7	15	4.52	2.1	1.0	0.12	1.1	0.4	0.4	0.2	0.6
13.5.-20.5.	0.3	48	4.21								
20.5.-27.5.	9.2	18	4.38	2.9	0.2	0.06	0.4	0.1	0.1	0.0	0.1
27.5.-1.10.	8.6	24	4.60	3.2	2.9	0.22	0.6	0.1	0.2	0.1	1.7

Table A7: Weekly values of precipitation quality at Noatun.

	Amount of preci- pitation	Conduc- tivity	pH	SO_4	Cl	Mg	NO_3	NH_4	Ca	K	Na
Week	mm	µS/cm		mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
1. - 4.6.	7.9	10	4.80	1.1	0.4	0.04	0.2	<0.1	<0.1	<0.1	0.3
4. - 11.6.	0.0										
11.6.- 18.6.	7.3	18	4.84	1.7	2.0	0.16	0.5	0.1	0.1	<0.1	1.1
18. - 25.6.	0.0										
25.6 - 1.7.	2.4	39	4.33	6.6	0.7	0.19	2.2	0.8	0.4	0.4	0.7
1. - 2.7.	0.0										
2. - 9.7.	7.3	19	4.55	2.6	0.2	0.08	0.9	0.2	0.2	0.3	0.2
9. - 16.7.	22.9	22	4.47	3.1	0.7	0.07	0.7	0.6	<0.1	0.2	0.5
16.7. 23.7.	5.1	33	4.15	3.7	0.6	0.09	0.7	<0.1	<0.1	<0.1	0.4
23. - 30.7.	3.8	21	4.41	2.9	0.5	0.10	0.8	0.3	0.1	0.2	0.4
30.7.- 1.8.	0.0										
1. - 6.8.	30.3	21	4.39	2.6	0.1	0.02	0.7	0.3	<0.1	<0.1	<0.1
6. - 13.8.	9.2	5	5.34	0.6	0.1	0.02	0.2	0.2	<0.1	<0.1	<0.1
13. - 20.8.	0.4	20	6.01								
20. - 27.8.	1.1	55	4.03	8.5	0.5	0.17	0.9	0.4	0.3	0.3	0.7
27.8 - 1.9.	0.0										
1.3 - 3.9.	0.0										

Table A7, cont.

	Amount of precipitation	Conductivity	pH	SO_4	Cl	Mg	NO_3	NH_4	Ca	K	Na
Week	mm	µS/cm		mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
3. - 10.9.	0.0										
10. - 17.9.	4.8	9	5.16	1.4	0.2	0.05	0.4	0.3	<0.1	0.1	0.2
17.9. 24.9.	0.9	28	4.78								
24.9. 1.10.	6.8	16	4.77	1.4	2.0	0.15	0.2	<0.1	<0.1	<0.1	1.1
1. - 8.10.	1.6	27	4.39	3.1	1.1	0.14	1.3	0.3	0.1	0.1	0.9
8. - 15.10.	9.2	9	4.86	0.8	0.2	0.03	0.5	<0.1	<0.1	<0.1	0.1
15. - 22.10.	1.9	33	4.39	3.5	2.0	0.18	1.5	0.4	0.2	<0.1	1.2
22. - 29.10.	0.5	50	4.67								
29.10- 1.11.	0.3	55	4.05								
1. - 5.11.	5.3	58	6.42	3.7	7.9	0.73	3.8	0.9	3.4	2.6	5.0
5. - 12.11.	6.1	16	5.49	0.8	2.7	0.19	1.0	0.3	0.3	0.8	1.5
12. - 19.11.	1.6	54	4.98	3.8	10.0	0.50	3.2	1.1	1.0	2.1	5.2
19. - 26.11.	2.9	13	4.83	0.7	1.7	0.11	0.4	<0.1	0.1	<0.1	0.8
26.11. 1.12.	2.9	21	5.21	1.6	3.2	0.26	0.8	0.2	0.4	0.8	1.6
1.12 - 3.12.	0.0										
3. - 10.12.	2.1	26	5.50	2.5	3.8	0.41	1.1	<0.1	1.0	1.3	1.8
10 - 17.12.	0.8	49	5.03								
17.- 24.12.	11.5	6	4.76	0.4	0.2	0.02	0.7	<0.1	<0.1	<0.1	0.2

Table A7, cont.

Week	Amount of precipitation mm	Conductivity µS/cm	pH	SO_4 mg/l	Cl mg/l	Mg mg/l	NO_3 mg/l	NH_4 mg/l	Ca mg/l	K mg/l	Na mg/l
24. - 31.12	0.6	105	3.98								
31.12- 1.1.	0.0										
1. - 7.1.	0.5	49	4.05								
7.1 - 14.1.	1.9	28	4.39	1.7	1.5	0.15	3.6	0.3	0.4	0.6	0.7
14. - 21.1.	0.0										
21.1.- 28.1.	6.7	12	4.88	1.1	1.5	0.13	0.7	<0.1	0.2	0.3	0.8
28.1. 1.2.	0.6	73	5.42	5.7	15.8		4.9			0.2	0.7
01. - 4.2.	0.2	36	5.70								
4.2. - 11.2.	0.0										
11.2 - 18.2.	0.3	64	4.28								
18. - 25.2.	2.9	33	4.28	2.5	1.2	0.12	2.8	0.2	0.4	0.3	0.6
25.2. 1.3.	0.1	88									
1. - 4.3.	0.2	30									
4.3. - 11.3.	14.6	9	4.86	0.5	0.3	0.04	0.7	<0.1	0.1	<0.1	0.2
11.3. 18.3.	1.9	14	5.23	2.0	1.4	0.17	0.6	0.1	0.6	0.4	0.8
18.3 - 25.3.	0.0										
25.3 - 1.4.	9.2	11	5.12	0.8	1.1	0.12	0.4	<0.1	0.2	0.2	0.6
1.4. - 8.4.	0.0										

Table A7, cont.

	Amount of precipitation	Conductivity	pH	SO_4	Cl	Mg	NO_3	NH_4	Ca	K	Na
Week	mm	µS/cm		mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
8.4. - 15.4.	0.0										
15.4.- 22.4.	0.0										
22.4. 29.4.	0.0										
29.4 - 1.5.	0.0										
1.5. - 6.5.	2.7	28	4.37	3.2	0.6	0.07	1.4	0.3	0.3	0.1	0.3
6.5. - 13.5.	1.6	19	4.52	2.0	0.5	0.08	1.4	0.3	0.2	0.1	0.4
13.5.- 20.5.	0.0										
20.5. 27.5.	2.2	20	4.30	2.8	0.2	0.04	0.4	<0.1	0.1	<0.1	0.2
27.5. 1.6.	12.4	20	4.63	2.7	1.1	0.12	0.4	0.1	0.1	0.2	0.6

Table A8: Weekly values of precipitation quality at Karpdalen started January 1991.

	Amount of preci- pitation	Conduc- tivity	pH	SO_4	Cl	Mg	NO_3	NH_4	Ca	K	Na
Week	mm	µS/cm		mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
1. - 7.1.	0.0										
7.1 - 14.1.	1.0	99	4.08	5.5	15.4	1.17	4.5	0.3	0.5	0.4	8.6
14. - 21.1.	0.9	150	3.87								
21.1.- 28.1.	12.9	21	4.72	1.4	3.7	0.26	0.2	<0.1	0.1	<0.1	2.0
28.1. 1.2.	0.4	37	4.98								
01. - 4.2.	0.1										
4.2. - 11.2.	0.2	104									
11.2 - 18.2.	0.2	89									
18. - 25.2.	2.9	73	3.86	6.2	3.1	0.27	4.0	0.4	0.3	0.2	1.7
25.2. 1.3.	0.7	83	4.05	4.8	17.2	1.01	0.8		0.4	0.6	8.9
1. - 4.3.	0.4	47	4.06								
4.3. - 11.3.	3.8	38	4.28	3.1	3.2	0.28	1.3	0.2	0.2	0.2	1.8
11.3. 18.3.	3.2	32	4.44	2.9	3.6	0.31	0.7	0.2	0.2	0.2	2.2
18.3 - 25.3.	0.0										
25.3 - 1.4.	15.6	42	4.39	3.3	7.0	0.56	0.3	<0.1	0.2	0.2	3.9
1.4. - 8.4.	0.0										

Table A8, Cont.

	Amount of precipitation	Conductivity	pH	SO_4	Cl	Mg	NO_3	NH_4	Ca	K	Na
Week	mm	µS/cm		mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
8.4. - 15.4.	0.0										
15.4.- 22.4.	0.0										
22.4. 29.4.	0.0										
29.4 - 1.5.	0.0										
1.5. - 6.5.	1.1	114	3.45	14.1	12.8	0.57	3.4	1.2	0.7	0.6	8.0
6.5. - 13.5.	0.4	148	3.11								
13.5.- 20.5.	0.0										
20.5. 27.5.	5.9	79	3.73	10.1	0.9	0.12	1.3	0.2	0.2	0.1	0.5
27.5. 1.6.	1.1	249	3.92	20.0	49.6	3.60	3.9	0.6	1.9	1.4	28.1

Table A9: Monthly and 3-months weightloss results for steel along the Russian-Norwegian border.

<table>
<tr><th colspan="9">1 month steel</th></tr>
<tr><th>Periode</th><th>Viksjøfjell</th><th>Karpdalen</th><th>Svanvik</th><th>Kobbfoss</th><th>Noatun</th><th>Sov1</th><th>Sov2</th><th>Sov3</th></tr>
<tr><td>6/90</td><td>25</td><td>7.7</td><td>5.1</td><td>6.7</td><td>7.2</td><td>4.8</td><td>10</td><td>10</td></tr>
<tr><td>7/90</td><td>39</td><td>16</td><td>11</td><td>22</td><td>13</td><td>26</td><td>50</td><td>16</td></tr>
<tr><td>8/90</td><td>58</td><td>34</td><td>11</td><td>5.7</td><td>7.2</td><td>3.4</td><td>60</td><td>28</td></tr>
<tr><td>9/90</td><td>72</td><td>32</td><td>12</td><td>7.9</td><td>7.9</td><td>6.3</td><td>57</td><td>38</td></tr>
<tr><td>10/90</td><td>44</td><td>30</td><td>9.4</td><td>9.7</td><td>7.6</td><td>9.1</td><td>58</td><td>49</td></tr>
<tr><td>11/90</td><td>36</td><td>21</td><td>15</td><td>16</td><td>15</td><td>5.9</td><td rowspan="3">99 (3mnth)</td><td rowspan="6">146 (6mnth)</td></tr>
<tr><td>12/90</td><td>69</td><td>35</td><td>16</td><td>15</td><td>17</td><td rowspan="2">20 (2mnth)</td></tr>
<tr><td>1/91</td><td>26</td><td>12</td><td>4.7</td><td>3.9</td><td>6.4</td></tr>
<tr><td>2/91</td><td>17</td><td>8.6</td><td>3.0</td><td>2.1</td><td>7.2</td><td>11</td><td>34</td></tr>
<tr><td>3/91</td><td>29</td><td>16</td><td>8.3</td><td>2.3</td><td>3.7</td><td rowspan="2">11 (2mnth)</td><td rowspan="2">66 (2mnth)</td></tr>
<tr><td>4/91</td><td>27</td><td>8.9</td><td>5.0</td><td>5.3</td><td>4.0</td></tr>
<tr><td>5/91</td><td>28</td><td>19</td><td>8.2</td><td>6.8</td><td>2.9</td><td></td><td></td><td></td></tr>
<tr><th colspan="9">3 months steel</th></tr>
<tr><td>6/90
7/90
8/90</td><td>108</td><td>66</td><td>40</td><td>44</td><td>37</td><td>29</td><td>90</td><td>63</td></tr>
<tr><td>9/90
10/90
11/90</td><td>143</td><td>21</td><td>42</td><td>36</td><td>32</td><td>19</td><td rowspan="2">154 (4mnth)</td><td rowspan="3">175 (8mnth)</td></tr>
<tr><td>12/90
1/91
2/91</td><td>98</td><td>46</td><td>19</td><td>16</td><td>21</td><td>38</td></tr>
<tr><td>3/91
4/91
5/91</td><td>97</td><td>54</td><td>39</td><td>31</td><td>20</td><td>13</td><td>92 (3mnth)</td></tr>
</table>

Table A10: Yearly weightloss results for steel, zinc, galvanized steel and Aluzinc (weightless in g/m^3·a). The Russian results are adjusted for a complete year.

1 year steel								
Periode	Viksjøfjell	Karpdalen	Svanvik	Kobbfoss	Noatun	Sov1	Sov2	Sov3
6/90 - 6/91	308	180	108	91	78	93	261	214
1 year zinc								
6/90 - 6/91	24	12	9.6	8.6	5.4	6.4	19	15
1 year galvanized steel								
6/91 - 6/91	17	7.8	4.3	4.2	3.3	4.8	16	11
1 year Aluzinc								
6/90 - 6/91	10	5.3	2.4	1.8	1.5	2.8	9.6	6.9

Table A11: Corrosion of open helixes of aluminium, galvanized steel, "Galfan" coated. (95% Zn, 5% Al) steel (corrosion rate µm/a). The Russian results are adjusted to a complete year.

Helix aluminium								
Periode	Viksjøfjell	Karpdalen	Svanvik	Kobbfoss	Noatun	Sov1	Sov2	Sov3
6/90 - 6/91	1.8	0.5	0.4	0.2	0.1	0.2	2.6	1.2
Helix galvanized steel								
6/90 - 6/91	4.0	1.6	1.2	0.9	0.7	1.2	3.2	2.2
Helix "Galfan-steel"								
Periode	Viksjøfjell	Karpdalen	Svanvik	Kobbfoss	Noatun	Sov1	Sov2	Sov3
6/90 - 6/91	-	1.0	0.6	0.5	0.4	0.9	2.8	1.9

APPENDIX B

Table B1: Distribution of windspeed with wind direction at Svanvik.

Station : SVANVIK
Period : 01.06.90 - 30.06.90

DIURNAL VARIATION OF WIND DIRECTIONS (%)

*) Wind-direction	Hours 01	04	07	10	13	16	19	22	Wind-rose
30	23.3	13.3	16.7	16.7	33.3	13.3	26.7	23.3	21.0
60	13.3	20.0	20.0	13.3	10.0	30.0	26.7	26.7	20.0
90	16.7	13.3	13.3	26.7	20.0	23.3	26.7	26.7	22.4
120	.0	13.3	16.7	13.3	6.7	6.7	6.7	3.3	7.2
150	.0	3.3	10.0	.0	6.7	.0	3.3	.0	3.5
180	6.7	3.3	.0	.0	.0	.0	6.7	.0	2.4
210	3.3	3.3	3.3	10.0	3.3	3.3	.0	10.0	4.6
240	3.3	10.0	10.0	10.0	10.0	6.7	.0	.0	6.3
270	3.3	.0	3.3	10.0	10.0	13.3	.0	.0	4.4
300	3.3	.0	3.3	.0	.0	.0	.0	.0	.6
330	.0	3.3	.0	.0	.0	.0	.0	.0	.4
360	.0	.0	.0	.0	.0	.0	.0	.0	.6
Calm	26.7	16.7	3.3	.0	.0	3.3	3.3	10.0	6.8
Nobs	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(720)
Average wind m/s	1.2	1.5	2.1	2.5	2.9	2.7	2.2	1.5	2.1

DISTRIBUTION OF WINDSPEED WITH WIND DIRECTIONS (%)

Class I: Windspeed .6 - 2.0 m/s
Class II: Windspeed 2.1 - 4.0 m/s
Class III: Windspeed 4.1 - 6.0 m/s
Class IV: Windspeed > 6.0 m/s

*) Wind-direction	Classes I	II	III	IV	Total	Nobs	Average wind m/s
30	10.6	9.6	.8	.0	21.0	(151)	2.2
60	10.1	9.7	.1	.0	20.0	(144)	2.1
90	10.8	11.0	.6	.0	22.4	(161)	2.1
120	3.2	3.2	.8	.0	7.2	(52)	2.3
150	2.9	.6	.0	.0	3.5	(25)	1.4
180	1.8	.4	.1	.0	2.4	(17)	1.7
210	2.5	1.2	.8	.0	4.6	(33)	2.3
240	1.9	3.6	.7	.0	6.3	(45)	2.6
270	.7	3.5	.3	.0	4.4	(32)	2.9
300	.4	.1	.0	.0	.6	(4)	1.4
330	.3	.1	.0	.0	.4	(3)	1.4
360	.3	.3	.0	.0	.6	(4)	1.9
Calm					6.8	(49)	
Total	45.6	43.3	4.3	.0	100.0	(720)	
Average wind m/s	1.4	2.7	4.5	.0			2.1

*) This number indicates central direction of sector

Table B1, cont.

Station : SVANVIK
Period : 01.07.90 - 31.07.90

DIURNAL VARIATION OF WIND DIRECTIONS (%)

*) Wind-direction	Hours 01	04	07	10	13	16	19	22	Wind-rose
30	19.4	29.0	16.1	16.1	25.8	29.0	22.6	29.0	24.7
60	29.0	9.7	25.8	19.4	16.1	16.1	35.5	12.9	18.3
90	.0	9.7	6.5	9.7	6.5	9.7	6.5	6.5	8.2
120	.0	.0	.0	3.2	3.2	3.2	3.2	3.2	2.3
150	6.5	.0	9.7	6.5	6.5	6.5	3.2	6.5	5.2
180	6.5	16.1	6.5	6.5	16.1	9.7	16.1	6.5	9.7
210	9.7	9.7	16.1	6.5	12.9	6.5	3.2	9.7	10.3
240	3.2	.0	6.5	16.1	9.7	6.5	3.2	.0	5.0
270	.0	.0	3.2	.0	.0	6.5	3.2	.0	1.7
300	3.2	3.2	3.2	.0	.0	.0	.0	.0	1.1
330	6.5	3.2	6.5	9.7	.0	3.2	.0	.0	4.0
360	.0	.0	.0	3.2	.0	3.2	.0	.0	.9
Calm	16.1	19.4	.0	3.2	3.2	.0	3.2	25.8	8.5
Nobs	(31)	(31)	(31)	(31)	(31)	(31)	(31)	(31)	(744)
Average wind m/s	1.3	1.5	2.0	2.3	2.5	2.2	1.8	1.5	1.9

DISTRIBUTION OF WINDSPEED WITH WIND DIRECTIONS (%)

Class I: Windspeed .6 - 2.0 m/s
Class II: Windspeed 2.1 - 4.0 m/s
Class III: Windspeed 4.1 - 6.0 m/s
Class IV: Windspeed > 6.0 m/s

*) Wind-direction	Classes I	II	III	IV	Total	Nobs	Average wind m/s
30	17.9	6.7	.1	.0	24.7	(184)	1.8
60	13.3	4.2	.8	.0	18.3	(136)	1.8
90	5.6	2.6	.0	.0	8.2	(61)	1.6
120	1.5	.8	.0	.0	2.3	(17)	1.9
150	2.8	2.4	.0	.0	5.2	(39)	1.9
180	3.1	6.2	.4	.0	9.7	(72)	2.6
210	2.3	6.9	1.2	.0	10.3	(77)	2.8
240	1.3	2.2	.8	.7	5.0	(37)	3.3
270	.9	.8	.0	.0	1.7	(13)	1.7
300	1.1	.0	.0	.0	1.1	(8)	1.0
330	3.2	.8	.0	.0	4.0	(30)	1.4
360	.8	.1	.0	.0	.9	(7)	1.6
Calm					8.5	(63)	
Total	53.9	33.6	3.4	.7	100.0	(744)	
Average wind m/s	1.3	2.8	4.5	6.5			1.9

*) This number indicates central direction of sector

Table B1, cont.

Station : SVANVIK
Period : 01.08.90 - 31.08.90

DIURNAL VARIATION OF WIND DIRECTIONS (%)

*) Wind-direction	Hours 01	04	07	10	13	16	19	22	Wind-rose
30	12.0	8.0	.0	4.0	8.0	3.8	8.0	8.0	5.6
60	16.0	4.0	12.0	4.0	8.0	3.8	16.0	16.0	8.8
90	4.0	.0	.0	4.0	12.0	15.4	12.0	12.0	8.0
120	.0	4.0	.0	4.0	8.0	7.7	16.0	4.0	6.3
150	4.0	.0	8.0	20.0	8.0	11.5	20.0	8.0	9.3
180	8.0	4.0	16.0	12.0	28.0	23.1	4.0	8.0	14.1
210	8.0	8.0	8.0	20.0	12.0	7.7	.0	12.0	7.8
240	4.0	4.0	4.0	12.0	16.0	7.7	8.0	.0	7.0
270	.0	4.0	.0	12.0	.0	11.5	4.0	4.0	3.5
300	4.0	4.0	.0	.0	.0	.0	.0	.0	1.3
330	.0	4.0	8.0	4.0	.0	3.8	.0	.0	3.2
360	4.0	.0	.0	4.0	.0	.0	.0	.0	.7
Calm	36.0	56.0	44.0	.0	.0	3.8	12.0	28.0	24.5
Nobs	(25)	(25)	(25)	(25)	(25)	(26)	(25)	(25)	(603)
Average wind m/s	.8	.7	1.1	1.7	1.9	1.5	1.2	1.0	1.2

DISTRIBUTION OF WINDSPEED WITH WIND DIRECTIONS (%)

Class I: Windspeed .6 - 2.0 m/s
Class II: Windspeed 2.1 - 4.0 m/s
Class III: Windspeed 4.1 - 6.0 m/s
Class IV: Windspeed > 6.0 m/s

*) Wind-direction	Classes I	II	III	IV	Total	Nobs	Average wind m/s
30	5.1	.5	.0	.0	5.6	(34)	1.3
60	8.8	.0	.0	.0	8.8	(53)	1.4
90	6.3	1.7	.0	.0	8.0	(48)	1.4
120	5.0	1.3	.0	.0	6.3	(38)	1.4
150	8.1	1.2	.0	.0	9.3	(56)	1.2
180	8.3	5.8	.0	.0	14.1	(85)	1.8
210	5.3	2.5	.0	.0	7.8	(47)	1.8
240	4.1	2.0	.8	.0	7.0	(42)	2.2
270	3.2	.3	.0	.0	3.5	(21)	1.2
300	1.3	.0	.0	.0	1.3	(8)	1.0
330	2.3	.8	.0	.0	3.2	(19)	1.3
360	.5	.2	.0	.0	.7	(4)	1.2
Calm					24.5	(148)	
Total	58.4	16.3	.8	.0	100.0	(603)	
Average wind m/s	1.2	2.6	4.9	.0			1.2

*) This number indicates central direction of sector

Table B1, cont.

Station : SVANVIK
Period : 01.09.90 - 30.09.90

DIURNAL VARIATION OF WIND DIRECTIONS (%)

*) Wind-direction	Hours 01	04	07	10	13	16	19	22	Wind-rose
30	3.3	6.7	.0	.0	6.7	10.0	3.3	.0	3.5
60	6.7	3.3	3.3	3.3	3.3	3.3	3.3	.0	3.1
90	3.3	3.3	3.3	.0	.0	.0	6.7	6.7	3.5
120	.0	3.3	.0	6.7	3.3	6.7	3.3	3.3	3.8
150	3.3	3.3	6.7	10.0	6.7	10.0	13.3	.0	5.8
180	3.3	6.7	13.3	3.3	6.7	10.0	10.0	10.0	10.7
210	16.7	16.7	16.7	20.0	26.7	20.0	13.3	20.0	15.7
240	6.7	6.7	10.0	26.7	20.0	13.3	6.7	6.7	12.1
270	3.3	.0	3.3	3.3	6.7	.0	.0	6.7	4.6
300	10.0	16.7	3.3	3.3	.0	3.3	.0	.0	3.9
330	6.7	3.3	6.7	3.3	.0	3.3	3.3	.0	3.2
360	16.7	13.3	13.3	13.3	16.7	13.3	13.3	13.3	13.6
Calm	20.0	16.7	20.0	6.7	3.3	6.7	23.3	33.3	16.7
Nobs	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(720)
Average wind m/s	1.5	1.6	1.8	3.0	2.9	2.5	1.7	1.5	2.0

DISTRIBUTION OF WINDSPEED WITH WIND DIRECTIONS (%)

Class I: Windspeed .6 - 2.0 m/s
Class II: Windspeed 2.1 - 4.0 m/s
Class III: Windspeed 4.1 - 6.0 m/s
Class IV: Windspeed > 6.0 m/s

*) Wind-direction	Classes I	II	III	IV	Total	Nobs	Average wind m/s
30	3.3	.1	.0	.0	3.5	(25)	1.1
60	3.1	.0	.0	.0	3.1	(22)	1.1
90	1.7	1.2	.6	.0	3.5	(25)	2.4
120	1.2	.7	1.7	.1	3.8	(27)	3.2
150	2.9	2.1	.8	.0	5.8	(42)	2.3
180	5.4	4.7	.6	.0	10.7	(77)	2.1
210	5.6	6.7	3.5	.0	15.7	(113)	2.7
240	4.7	5.1	2.2	.0	12.1	(87)	2.7
270	3.1	1.5	.0	.0	4.6	(33)	1.6
300	3.6	.3	.0	.0	3.9	(28)	1.2
330	2.4	.3	.6	.0	3.2	(23)	1.8
360	4.4	6.0	3.2	.0	13.6	(98)	2.9
Calm					16.7	(120)	
Total	41.4	28.8	13.1	.1	100.0	(720)	
Average wind m/s	1.2	2.9	4.6	6.5			2.0

*) This number indicates central direction of sector

Table B1, cont.

Station : SVANVIK
Period : 01.10.90 - 31.10.90

DIURNAL VARIATION OF WIND DIRECTIONS (%)

*) Wind-direction	01	04	07	10	13	16	19	22	Wind-rose
	Hours								
30	6.5	.0	3.2	.0	3.2	.0	.0	3.2	2.6
60	.0	3.2	3.2	3.2	.0	.0	.0	.0	1.2
90	3.2	.0	.0	.0	.0	.0	3.2	3.2	1.2
120	.0	.0	.0	3.2	.0	3.2	3.2	3.2	1.2
150	3.2	16.1	9.7	3.2	6.5	9.7	3.2	.0	7.4
180	16.1	19.4	16.1	19.4	32.3	19.4	25.8	22.6	21.3
210	22.6	19.4	22.6	22.6	19.4	19.4	16.1	19.4	20.9
240	16.1	9.7	16.1	16.1	6.5	9.7	12.9	12.9	11.0
270	12.9	6.5	9.7	3.2	.0	3.2	3.2	16.1	7.1
300	3.2	6.5	6.5	19.4	16.1	12.9	9.7	3.2	8.6
330	3.2	3.2	.0	.0	3.2	6.5	.0	3.2	2.8
360	3.2	3.2	.0	6.5	6.5	6.5	6.5	.0	3.6
Calm	9.7	12.9	12.9	3.2	6.5	9.7	16.1	12.9	11.0
Nobs	(31)	(31)	(31)	(31)	(31)	(31)	(31)	(31)	(743)
Average wind m/s	2.3	2.4	2.6	3.1	3.2	3.0	2.6	2.4	2.7

DISTRIBUTION OF WINDSPEED WITH WIND DIRECTIONS (%)

Class I: Windspeed .6 - 2.0 m/s
Class II: Windspeed 2.1 - 4.0 m/s
Class III: Windspeed 4.1 - 6.0 m/s
Class IV: Windspeed > 6.0 m/s

*) Wind-direction	I	II	III	IV	Total	Nobs	Average wind m/s
	Classes						
30	2.2	.1	.3	.0	2.6	(19)	1.6
60	1.2	.0	.0	.0	1.2	(9)	1.2
90	.7	.3	.3	.0	1.2	(9)	2.1
120	.5	.4	.3	.0	1.2	(9)	2.8
150	1.6	3.4	2.3	.1	7.4	(55)	3.3
180	3.6	12.2	5.1	.3	21.3	(158)	3.3
210	4.3	8.5	7.1	.9	20.9	(155)	3.4
240	5.8	2.6	2.4	.3	11.0	(82)	2.6
270	5.0	1.3	.8	.0	7.1	(53)	2.0
300	3.1	2.2	3.2	.1	8.6	(64)	3.2
330	1.3	1.1	.4	.0	2.8	(21)	2.5
360	1.6	1.1	.8	.1	3.6	(27)	2.8
Calm					11.0	(82)	
Total	31.0	33.1	23.0	1.9	100.0	(743)	
Average wind m/s	1.2	3.1	4.9	6.5			2.7

*) This number indicates central direction of sector

Table B1, cont.

Station : SVANVIK
Period : 01.11.90 - 30.11.90

DIURNAL VARIATION OF WIND DIRECTIONS (%)

*) Wind-direction	Hours 01	04	07	10	13	16	19	22	Wind-rose
30	.0	.0	3.3	.0	3.3	3.3	.0	3.3	1.7
60	3.3	6.7	6.7	6.7	6.7	6.7	3.3	3.3	5.3
90	3.3	.0	.0	.0	.0	.0	10.0	6.7	2.5
120	6.7	3.3	.0	.0	.0	.0	3.3	.0	1.2
150	.0	3.3	3.3	3.3	6.7	.0	.0	.0	1.9
180	10.0	13.3	20.0	10.0	13.3	16.7	13.3	20.0	14.9
210	16.7	10.0	6.7	10.0	13.3	20.0	20.0	16.7	14.3
240	13.3	3.3	13.3	13.3	6.7	.0	10.0	6.7	7.8
270	6.7	10.0	3.3	6.7	3.3	10.0	6.7	3.3	6.7
300	6.7	10.0	6.7	10.0	10.0	10.0	10.0	13.3	10.3
330	.0	6.7	13.3	10.0	6.7	3.3	3.3	3.3	4.6
360	6.7	3.3	.0	.0	.0	.0	.0	.0	1.8
Calm	26.7	30.0	23.3	30.0	30.0	30.0	20.0	23.3	27.1
Nobs	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(720)
Average wind m/s	1.6	1.4	1.7	1.7	1.5	1.7	2.1	1.7	1.7

DISTRIBUTION OF WINDSPEED WITH WIND DIRECTIONS (%)

Class I: Windspeed .6 - 2.0 m/s
Class II: Windspeed 2.1 - 4.0 m/s
Class III: Windspeed 4.1 - 6.0 m/s
Class IV: Windspeed > 6.0 m/s

*) Wind-direction	Classes I	II	III	IV	Total	Nobs	Average wind m/s
30	1.0	.7	.0	.0	1.7	(12)	1.8
60	4.6	.7	.0	.0	5.3	(38)	1.5
90	1.7	.8	.0	.0	2.5	(18)	2.0
120	1.0	.3	.0	.0	1.2	(9)	1.4
150	1.9	.0	.0	.0	1.9	(14)	1.0
180	7.6	6.3	1.0	.0	14.9	(107)	2.2
210	8.5	4.7	1.1	.0	14.3	(103)	2.0
240	5.7	1.8	.3	.0	7.8	(56)	1.5
270	3.1	2.5	1.1	.0	6.7	(48)	2.5
300	3.5	3.9	2.5	.4	10.3	(74)	3.0
330	1.5	2.4	.7	.0	4.6	(33)	2.8
360	.6	.4	.8	.0	1.8	(13)	3.2
Calm					27.1	(195)	
Total	40.6	24.4	7.5	.4	100.0	(720)	
Average wind m/s	1.2	2.9	4.7	6.8			1.7

*) This number indicates central direction of sector

Table B1, cont.

Station : SVANVIK
Period : 01.12.90 - 31.12.90

DIURNAL VARIATION OF WIND DIRECTIONS (%)

*) Wind-direction	Hours 01	04	07	10	13	16	19	22	Wind-rose
30	.0	.0	.0	.0	.0	3.2	.0	3.2	.3
60	3.2	3.2	.0	3.2	3.2	3.2	.0	.0	2.0
90	.0	.0	.0	.0	3.2	.0	3.2	.0	.3
120	3.2	.0	.0	.0	.0	.0	.0	3.2	.7
150	6.5	3.2	9.7	12.9	9.7	12.9	12.9	9.7	9.5
180	22.6	19.4	25.8	12.9	12.9	16.1	22.6	19.4	18.3
210	22.6	25.8	22.6	32.3	29.0	19.4	9.7	19.4	23.5
240	16.1	16.1	6.5	6.5	22.6	16.1	22.6	19.4	14.9
270	.0	3.2	.0	3.2	3.2	3.2	3.2	.0	2.0
300	3.2	3.2	3.2	6.5	.0	3.2	3.2	6.5	3.8
330	.0	.0	.0	.0	.0	.0	.0	.0	.7
360	.0	.0	6.5	.0	3.2	3.2	.0	.0	1.5
Calm	22.6	25.8	25.8	22.6	12.9	19.4	22.6	19.4	22.6
Nobs	(31)	(31)	(31)	(31)	(31)	(31)	(31)	(31)	(744)
Average wind m/s	2.8	2.8	3.1	2.9	3.1	2.7	2.8	2.6	2.8

DISTRIBUTION OF WINDSPEED WITH WIND DIRECTIONS (%)

Class I: Windspeed .6 - 2.0 m/s
Class II: Windspeed 2.1 - 4.0 m/s
Class III: Windspeed 4.1 - 6.0 m/s
Class IV: Windspeed > 6.0 m/s

*) Wind-direction	Classes I	II	III	IV	Total	Nobs	Average wind m/s
30	.3	.0	.0	.0	.3	(2)	1.0
60	1.6	.4	.0	.0	2.0	(15)	1.3
90	.3	.0	.0	.0	.3	(2)	1.4
120	.3	.4	.0	.0	.7	(5)	2.6
150	2.2	2.7	2.7	2.0	9.5	(71)	4.2
180	4.6	7.9	4.2	1.6	18.3	(136)	3.3
210	3.9	9.7	8.6	1.3	23.5	(175)	3.7
240	4.4	3.6	4.8	2.0	14.9	(111)	3.8
270	.8	.7	.4	.1	2.0	(15)	3.0
300	2.2	.7	.0	.9	3.8	(28)	3.1
330	.3	.0	.1	.3	.7	(5)	4.4
360	.5	.8	.0	.1	1.5	(11)	2.8
Calm					22.6	(168)	
Total	21.2	26.9	20.8	8.5	100.0	(744)	
Average wind m/s	1.2	3.1	4.8	7.5			2.8

*) This number indicates central direction of sector

Table B1, cont.

Station : SVANVIK
Period : 01.01.91 - 31.01.91

DIURNAL VARIATION OF WIND DIRECTIONS (%)

*) Wind-direction	Hours 01	04	07	10	13	16	19	22	Wind-rose
30	.0	.0	.0	.0	3.2	.0	.0	3.2	1.3
60	.0	.0	6.5	6.5	.0	.0	.0	3.2	2.4
90	3.2	.0	.0	.0	3.2	3.2	.0	.0	1.3
120	.0	3.2	.0	.0	.0	.0	.0	3.2	1.6
150	6.5	3.2	.0	.0	3.2	6.5	9.7	9.7	3.9
180	9.7	16.1	12.9	19.4	12.9	12.9	22.6	3.2	13.7
210	9.7	12.9	19.4	12.9	16.1	16.1	6.5	12.9	12.4
240	12.9	6.5	12.9	16.1	16.1	9.7	16.1	25.8	15.6
270	12.9	9.7	9.7	6.5	6.5	12.9	6.5	3.2	9.0
300	3.2	6.5	3.2	.0	.0	.0	.0	.0	2.6
330	6.5	6.5	.0	3.2	3.2	6.5	3.2	6.5	4.0
360	.0	.0	.0	.0	3.2	6.5	6.5	.0	1.3
Calm	35.5	35.5	35.5	35.5	32.3	25.8	29.0	29.0	30.8
Nobs	(31)	(31)	(31)	(31)	(31)	(31)	(31)	(31)	(744)
Average wind m/s	2.1	2.1	2.1	2.4	2.3	2.6	2.4	2.3	2.3

DISTRIBUTION OF WINDSPEED WITH WIND DIRECTIONS (%)

Class I: Windspeed .6 - 2.0 m/s
Class II: Windspeed 2.1 - 4.0 m/s
Class III: Windspeed 4.1 - 6.0 m/s
Class IV: Windspeed > 6.0 m/s

*) Wind-direction	Classes I	II	III	IV	Total	Nobs	Average wind m/s
30	.8	.5	.0	.0	1.3	(10)	1.8
60	1.9	.5	.0	.0	2.4	(18)	1.5
90	.5	.8	.0	.0	1.3	(10)	2.4
120	.4	1.1	.1	.0	1.6	(12)	2.7
150	1.9	1.1	.1	.8	3.9	(29)	3.9
180	4.7	4.4	2.0	2.6	13.7	(102)	3.7
210	4.7	4.0	2.2	1.5	12.4	(92)	3.1
240	4.8	6.2	3.6	.9	15.6	(116)	3.2
270	1.9	3.8	3.1	.3	9.0	(67)	3.5
300	1.3	.4	.7	.1	2.6	(19)	2.6
330	1.2	1.5	1.2	.1	4.0	(30)	3.1
360	.5	.8	.0	.0	1.3	(10)	2.3
Calm					30.8	(229)	
Total	24.7	25.1	13.0	6.3	100.0	(744)	
Average wind m/s	1.3	3.0	4.9	8.2			2.3

*) This number indicates central direction of sector

Table B1, cont.

Station : SVANVIK
Period : 01.02.91 - 28.02.91

DIURNAL VARIATION OF WIND DIRECTIONS (%)

*) Wind-direction	Hours 01	04	07	10	13	16	19	22	Wind-rose
30	.0	.0	.0	.0	.0	.0	.0	.0	.0
60	.0	.0	.0	.0	.0	.0	.0	.0	.0
90	.0	.0	.0	.0	.0	.0	.0	.0	.0
120	.0	.0	.0	.0	.0	.0	.0	.0	.1
150	.0	.0	.0	.0	3.6	3.6	.0	.0	.6
180	7.1	3.6	21.4	14.3	17.9	10.7	7.1	10.7	11.6
210	32.1	32.1	17.9	25.0	21.4	28.6	17.9	25.0	25.1
240	10.7	14.3	17.9	25.0	28.6	14.3	32.1	21.4	21.1
270	7.1	7.1	3.6	7.1	.0	.0	.0	3.6	2.7
300	3.6	.0	.0	.0	.0	3.6	3.6	.0	1.6
330	.0	.0	.0	3.6	3.6	.0	.0	3.6	1.5
360	3.6	3.6	3.6	.0	.0	3.6	3.6	.0	2.7
Calm	35.7	39.3	35.7	25.0	25.0	35.7	35.7	35.7	32.9
Nobs	(28)	(28)	(28)	(28)	(28)	(28)	(28)	(28)	(672)
Average wind m/s	1.6	1.4	1.2	1.6	1.8	1.6	1.6	1.5	1.6

DISTRIBUTION OF WINDSPEED WITH WIND DIRECTIONS (%)

Class I: Windspeed .6 - 2.0 m/s
Class II: Windspeed 2.1 - 4.0 m/s
Class III: Windspeed 4.1 - 6.0 m/s
Class IV: Windspeed > 6.0 m/s

*) Wind-direction	Classes I	II	III	IV	Total	Nobs	Average wind m/s
30	.0	.0	.0	.0	.0	(0)	.0
60	.0	.0	.0	.0	.0	(0)	.0
90	.0	.0	.0	.0	.0	(0)	.0
120	.1	.0	.0	.0	.1	(1)	.7
150	.6	.0	.0	.0	.6	(4)	1.2
180	6.3	3.6	1.5	.3	11.6	(78)	2.4
210	13.7	9.4	2.1	.0	25.1	(169)	2.2
240	12.9	8.0	.1	.0	21.1	(142)	1.8
270	2.2	.4	.0	.0	2.7	(18)	1.2
300	.7	.9	.0	.0	1.6	(11)	2.0
330	.1	1.3	.0	.0	1.5	(10)	3.0
360	.3	1.9	.4	.0	2.7	(18)	3.1
Calm					32.9	(221)	
Total	37.1	25.6	4.2	.3	100.0	(672)	
Average wind m/s	1.3	2.8	4.9	6.3			1.6

*) This number indicates central direction of sector

Table B1, cont.

Station : SVANVIK
Period : 01.03.91 - 31.03.91

DIURNAL VARIATION OF WIND DIRECTIONS (%)

*) Wind-direction	Hours 01	04	07	10	13	16	19	22	Wind-rose
30	.0	.0	3.2	.0	6.5	.0	3.2	3.2	2.2
60	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.9
90	3.2	3.2	.0	3.2	6.5	3.2	3.2	.0	3.0
120	.0	.0	3.2	3.2	.0	3.2	3.2	.0	1.7
150	3.2	3.2	.0	9.7	6.5	6.5	16.1	6.5	5.8
180	19.4	16.1	16.1	19.4	22.6	22.6	12.9	22.6	18.1
210	6.5	3.2	9.7	19.4	19.4	19.4	3.2	12.9	11.2
240	6.5	6.5	9.7	12.9	12.9	9.7	6.5	3.2	8.7
270	6.5	3.2	3.2	3.2	3.2	.0	6.5	.0	3.9
300	3.2	.0	.0	3.2	3.2	3.2	.0	3.2	1.9
330	.0	.0	3.2	.0	.0	.0	6.5	6.5	1.2
360	.0	3.2	3.2	3.2	3.2	12.9	.0	.0	3.4
Calm	45.2	54.8	41.9	16.1	9.7	12.9	32.3	35.5	32.1
Nobs	(31)	(31)	(31)	(31)	(31)	(31)	(31)	(31)	(744)
Average wind m/s	1.3	1.2	1.6	2.1	2.3	1.8	1.4	1.4	1.6

DISTRIBUTION OF WINDSPEED WITH WIND DIRECTIONS (%)

Class I: Windspeed .6 - 2.0 m/s
Class II: Windspeed 2.1 - 4.0 m/s
Class III: Windspeed 4.1 - 6.0 m/s
Class IV: Windspeed > 6.0 m/s

*) Wind-direction	Classes I	II	III	IV	Total	Nobs	Average wind m/s
30	2.2	.0	.0	.0	2.2	(16)	1.2
60	4.4	2.4	.0	.0	6.9	(51)	1.8
90	2.0	.9	.0	.0	3.0	(22)	1.7
120	1.2	.5	.0	.0	1.7	(13)	1.8
150	2.2	2.2	1.5	.0	5.8	(43)	2.7
180	7.3	9.8	1.1	.0	18.1	(135)	2.3
210	7.4	3.4	.4	.0	11.2	(83)	1.8
240	5.8	3.0	.0	.0	8.7	(65)	1.7
270	2.8	.7	.4	.0	3.9	(29)	1.9
300	1.1	.7	.1	.0	1.9	(14)	2.0
330	.1	1.1	.0	.0	1.2	(9)	2.6
360	.8	.3	.9	1.3	3.4	(25)	5.2
Calm					32.1	(239)	
Total	37.2	24.9	4.4	1.3	100.0	(744)	
Average wind m/s	1.3	2.8	4.8	8.1			1.6

*) This number indicates central direction of sector

Table B1, cont.

Station : SVANVIK
Period : 01.04.91 - 30.04.91

DIURNAL VARIATION OF WIND DIRECTIONS (%)

*) Wind-direction	Hours 01	04	07	10	13	16	19	22	Wind-rose
30	.0	6.7	3.3	10.0	.0	.0	6.7	.0	3.5
60	.0	3.3	.0	.0	3.3	3.3	3.3	.0	1.8
90	.0	.0	3.3	3.3	3.3	6.7	3.3	.0	2.4
120	3.3	.0	.0	.0	.0	6.7	.0	.0	1.0
150	3.3	3.3	3.3	6.7	10.0	6.7	10.0	3.3	6.7
180	16.7	16.7	16.7	20.0	20.0	16.7	13.3	13.3	16.4
210	20.0	23.3	36.7	36.7	26.7	26.7	23.3	23.3	25.8
240	6.7	6.7	6.7	6.7	6.7	10.0	10.0	10.0	8.5
270	.0	.0	3.3	3.3	6.7	3.3	6.7	3.3	3.1
300	3.3	.0	3.3	6.7	.0	3.3	3.3	.0	1.8
330	3.3	3.3	.0	3.3	6.7	6.7	3.3	3.3	4.6
360	3.3	.0	3.3	3.3	16.7	10.0	3.3	3.3	5.7
Calm	40.0	36.7	20.0	.0	.0	.0	13.3	40.0	18.9
Nobs	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(720)
Average wind m/s	1.6	1.8	2.3	3.0	3.2	2.9	2.1	1.6	2.3

DISTRIBUTION OF WINDSPEED WITH WIND DIRECTIONS (%)

Class I: Windspeed .6 - 2.0 m/s
Class II: Windspeed 2.1 - 4.0 m/s
Class III: Windspeed 4.1 - 6.0 m/s
Class IV: Windspeed > 6.0 m/s

*) Wind-direction	Classes I	II	III	IV	Total	Nobs	Average wind m/s
30	1.8	1.7	.0	.0	3.5	(25)	2.0
60	1.2	.6	.0	.0	1.8	(13)	1.4
90	1.0	1.4	.0	.0	2.4	(17)	2.1
120	.8	.0	.1	.0	1.0	(7)	1.9
150	2.6	1.0	1.1	1.9	6.7	(48)	4.0
180	3.6	9.2	3.6	.0	16.4	(118)	3.1
210	6.3	12.6	6.7	.3	25.8	(186)	3.1
240	2.6	3.9	1.9	.0	8.5	(61)	2.9
270	2.1	1.0	.0	.0	3.1	(22)	1.7
300	1.7	.1	.0	.0	1.8	(13)	1.5
330	3.1	1.5	.0	.0	4.6	(33)	1.8
360	3.8	1.9	.0	.0	5.7	(41)	1.7
Calm					18.9	(136)	
Total	30.6	34.9	13.5	2.2	100.0	(720)	
Average wind m/s	1.3	3.0	4.7	7.8			2.3

*) This number indicates central direction of sector

Table B1, cont.

Station : SVANVIK
Period : 01.05.91 - 31.05.91

DIURNAL VARIATION OF WIND DIRECTIONS (%)

*) Wind-direction	Hours 01	04	07	10	13	16	19	22	Wind-rose
30	.0	16.7	16.7	14.3	.0	.0	.0	40.0	14.1
60	16.7	16.7	16.7	.0	33.3	60.0	80.0	20.0	27.4
90	.0	16.7	16.7	.0	.0	20.0	.0	20.0	13.3
120	.0	.0	.0	28.6	33.3	.0	.0	.0	5.9
150	.0	.0	16.7	.0	16.7	.0	.0	.0	3.0
180	.0	.0	.0	14.3	.0	.0	.0	.0	2.2
210	.0	16.7	16.7	14.3	.0	.0	20.0	.0	9.6
240	16.7	.0	.0	14.3	16.7	20.0	.0	.0	8.1
270	.0	.0	.0	.0	.0	.0	.0	.0	.0
300	.0	.0	.0	.0	.0	.0	.0	.0	.0
330	.0	.0	.0	.0	.0	.0	.0	.0	.0
360	33.3	16.7	.0	14.3	.0	.0	.0	.0	6.7
Calm	33.3	16.7	16.7	.0	.0	.0	.0	20.0	9.6
Nobs	(6)	(6)	(6)	(7)	(6)	(5)	(5)	(5)	(135)
Average wind m/s	.9	1.4	2.1	2.4	2.7	2.3	1.2	.8	1.7

DISTRIBUTION OF WINDSPEED WITH WIND DIRECTIONS (%)

Class I: Windspeed .6 - 2.0 m/s
Class II: Windspeed 2.1 - 4.0 m/s
Class III: Windspeed 4.1 - 6.0 m/s
Class IV: Windspeed > 6.0 m/s

*) Wind-direction	Classes I	II	III	IV	Total	Nobs	Average wind m/s
30	7.4	5.9	.7	.0	14.1	(19)	1.8
60	22.2	5.2	.0	.0	27.4	(37)	1.3
90	7.4	5.9	.0	.0	13.3	(18)	1.8
120	1.5	4.4	.0	.0	5.9	(8)	2.5
150	.7	2.2	.0	.0	3.0	(4)	2.6
180	.7	1.5	.0	.0	2.2	(3)	2.1
210	4.4	4.4	.7	.0	9.6	(13)	2.6
240	5.2	2.2	.7	.0	8.1	(11)	2.2
270	.0	.0	.0	.0	.0	(0)	.0
300	.0	.0	.0	.0	.0	(0)	.0
330	.0	.0	.0	.0	.0	(0)	.0
360	3.7	3.0	.0	.0	6.7	(9)	1.7
Calm					9.6	(13)	
Total	53.3	34.8	2.2	.0	100.0	(135)	
Average wind m/s	1.2	2.7	4.1	.0			1.7

*) This number indicates central direction of sector

Table B2: Distribution of windspeed with wind direction at Viksjøfjell.

Station : VIKSJØFJELL
Period : 01.06.90 - 30.06.90

DIURNAL VARIATION OF WIND DIRECTIONS (%)

*) Wind-direction	Hours 01	04	07	10	13	16	19	22	Wind-rose
30	13.3	13.3	13.3	10.0	16.7	30.0	16.7	23.3	16.2
60	20.0	23.3	23.3	30.0	20.0	16.7	26.7	10.0	21.5
90	10.0	10.0	13.3	10.0	6.7	10.0	16.7	10.0	11.4
120	6.7	.0	3.3	3.3	10.0	10.0	6.7	16.7	6.7
150	10.0	10.0	3.3	3.3	3.3	.0	.0	6.7	5.0
180	13.3	6.7	3.3	3.3	6.7	6.7	3.3	10.0	6.1
210	3.3	10.0	3.3	6.7	6.7	3.3	6.7	3.3	7.2
240	10.0	13.3	20.0	16.7	13.3	13.3	.0	3.3	9.4
270	.0	.0	.0	.0	.0	.0	6.7	.0	1.2
300	.0	3.3	3.3	.0	.0	.0	.0	.0	.8
330	3.3	.0	.0	.0	.0	.0	.0	.0	1.1
360	10.0	10.0	13.3	16.7	16.7	10.0	16.7	16.7	13.2
Calm	.0	.0	.0	.0	.0	.0	.0	.0	.0
Nobs	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(720)
Average wind m/s	5.6	5.3	5.4	5.7	6.0	6.1	5.7	5.4	5.6

DISTRIBUTION OF WINDSPEED WITH WIND DIRECTIONS (%)

Class I: Windspeed .4 - 2.0 m/s
Class II: Windspeed 2.1 - 4.0 m/s
Class III: Windspeed 4.1 - 6.0 m/s
Class IV: Windspeed > 6.0 m/s

*) Wind-direction	Classes I	II	III	IV	Total	Nobs	Average wind m/s
30	.1	2.2	3.8	10.1	16.2	(117)	7.1
60	1.0	3.1	6.7	10.8	21.5	(155)	5.7
90	.7	4.3	5.4	1.0	11.4	(82)	4.2
120	.3	1.1	3.5	1.8	6.7	(48)	5.3
150	.7	2.4	1.8	.1	5.0	(36)	3.8
180	.3	1.8	2.6	1.4	6.1	(44)	4.7
210	.1	1.5	2.4	3.2	7.2	(52)	5.9
240	.3	1.2	3.9	4.0	9.4	(68)	6.0
270	.1	.8	.1	.1	1.2	(9)	3.3
300	.0	.7	.1	.0	.8	(6)	2.9
330	.0	.7	.3	.1	1.1	(8)	3.6
360	.1	1.5	2.9	8.6	13.2	(95)	6.4
Calm					.0	(0)	
Total	3.7	21.4	33.5	41.4	100.0	(720)	
Average wind m/s	1.5	3.1	5.0	7.8			5.6

*) This number indicates central direction of sector

Table B2, cont.

Station : VIKSJØFJELL
Period : 01.07.90 - 31.07.90

DIURNAL VARIATION OF WIND DIRECTIONS (%)

*) Wind-direction	Hours 01	04	07	10	13	16	19	22	Wind-rose
30	16.1	16.1	19.4	16.1	22.6	20.0	22.6	16.1	18.0
60	3.2	3.2	3.2	3.2	3.2	6.7	3.2	3.2	4.3
90	.0	.0	6.5	6.5	9.7	6.7	12.9	9.7	6.6
120	9.7	16.1	9.7	6.5	9.7	10.0	6.5	12.9	10.8
150	16.1	9.7	6.5	6.5	3.2	3.3	19.4	9.7	9.3
180	9.7	9.7	12.9	19.4	16.1	13.3	.0	16.1	10.1
210	12.9	9.7	9.7	6.5	9.7	10.0	16.1	6.5	10.5
240	3.2	3.2	.0	3.2	.0	.0	.0	3.2	2.3
270	3.2	.0	3.2	.0	.0	3.3	.0	3.2	1.4
300	.0	3.2	3.2	6.5	3.2	.0	.0	.0	2.4
330	12.9	12.9	12.9	6.5	9.7	6.7	9.7	6.5	8.6
360	12.9	16.1	12.9	19.4	12.9	20.0	9.7	12.9	15.5
Calm	.0	.0	.0	.0	.0	.0	.0	.0	.0
Nobs	(31)	(31)	(31)	(31)	(31)	(30)	(31)	(31)	(740)
Average wind m/s	5.7	5.6	5.8	6.0	6.0	6.1	5.3	5.2	5.7

DISTRIBUTION OF WINDSPEED WITH WIND DIRECTIONS (%)

Class I: Windspeed .4 - 2.0 m/s
Class II: Windspeed 2.1 - 4.0 m/s
Class III: Windspeed 4.1 - 6.0 m/s
Class IV: Windspeed > 6.0 m/s

*) Wind-direction	Classes I	II	III	IV	Total	Nobs	Average wind m/s
30	.4	2.8	5.7	9.1	18.0	(133)	6.2
60	.7	1.5	.9	1.2	4.3	(32)	4.3
90	.3	2.6	3.1	.7	6.6	(49)	4.2
120	.0	5.1	4.2	1.5	10.8	(80)	4.3
150	.4	2.8	3.8	2.3	9.3	(69)	4.8
180	.5	1.1	3.9	4.6	10.1	(75)	6.0
210	.7	.4	1.8	7.7	10.5	(78)	7.8
240	1.4	.5	.3	.1	2.3	(17)	2.7
270	.1	.5	.1	.5	1.4	(10)	4.8
300	.3	.1	1.8	.3	2.4	(18)	4.6
330	.5	.4	2.4	5.3	8.6	(64)	6.1
360	.7	2.2	4.1	8.6	15.5	(115)	6.5
Calm					.0	(0)	
Total	5.9	20.1	32.0	41.9	100.0	(740)	
Average wind m/s	1.5	3.1	5.0	8.1			5.7

*) This number indicates central direction of sector

Table B2, cont.

Station : VIKSJØFJELL
Period : 01.08.90 - 31.08.90

DIURNAL VARIATION OF WIND DIRECTIONS (%)

*) Wind-direction	Hours 01	04	07	10	13	16	19	22	Wind-rose
30	9.7	6.5	9.7	6.5	6.5	12.9	9.7	6.5	8.5
60	3.2	6.5	.0	3.2	.0	6.5	9.7	6.5	5.2
90	3.2	3.2	.0	3.2	9.7	9.7	9.7	3.2	5.9
120	3.2	6.5	9.7	12.9	9.7	16.1	22.6	6.5	10.6
150	12.9	12.9	25.8	16.1	9.7	9.7	9.7	25.8	15.3
180	19.4	3.2	6.5	12.9	16.1	9.7	19.4	16.1	14.0
210	25.8	22.6	22.6	12.9	9.7	9.7	12.9	16.1	15.5
240	6.5	22.6	9.7	12.9	16.1	12.9	.0	12.9	11.2
270	3.2	3.2	.0	3.2	.0	.0	3.2	.0	2.0
300	.0	6.5	9.7	6.5	9.7	6.5	.0	.0	4.4
330	3.2	3.2	6.5	3.2	3.2	6.5	.0	.0	2.8
360	9.7	3.2	.0	6.5	9.7	.0	3.2	6.5	4.6
Calm	.0	.0	.0	.0	.0	.0	.0	.0	.0
Nobs	(31)	(31)	(31)	(31)	(31)	(31)	(31)	(31)	(744)
Average wind m/s	4.7	4.2	4.3	4.7	4.5	4.3	4.3	4.8	4.5

DISTRIBUTION OF WINDSPEED WITH WIND DIRECTIONS (%)

Class I: Windspeed .4 - 2.0 m/s
Class II: Windspeed 2.1 - 4.0 m/s
Class III: Windspeed 4.1 - 6.0 m/s
Class IV: Windspeed > 6.0 m/s

*) Wind-direction	Classes I	II	III	IV	Total	Nobs	Average wind m/s
30	.7	2.4	2.7	2.7	8.5	(63)	5.6
60	1.2	2.0	.9	1.1	5.2	(39)	3.7
90	.9	2.8	.4	1.7	5.9	(44)	3.9
120	.5	5.6	3.0	1.5	10.6	(79)	4.1
150	1.5	6.5	7.0	.4	15.3	(114)	3.9
180	.5	3.9	8.1	1.5	14.0	(104)	4.6
210	1.1	2.7	6.0	5.6	15.5	(115)	5.7
240	1.1	3.4	5.5	1.2	11.2	(83)	4.4
270	.7	1.2	.1	.0	2.0	(15)	2.7
300	1.1	1.6	1.5	.3	4.4	(33)	3.6
330	.8	.4	1.2	.4	2.8	(21)	4.0
360	.5	1.3	.8	1.9	4.6	(34)	5.1
Calm					.0	(0)	
Total	10.6	33.9	37.2	18.3	100.0	(744)	
Average wind m/s	1.5	3.1	5.0	7.9			4.5

*) This number indicates central direction of sector

Table B2, cont.

Station : VIKSJØFJELL
Period : 01.09.90 - 30.09.90

DIURNAL VARIATION OF WIND DIRECTIONS (%)

*) Wind-direction	01	04	07	10	13	16	19	22	Wind-rose
30	3.3	6.7	3.3	6.7	3.3	10.0	3.4	3.3	5.4
60	6.7	6.7	6.7	6.7	10.0	3.3	6.9	3.3	5.7
90	3.3	.0	.0	.0	.0	.0	.0	6.7	1.3
120	6.7	6.7	10.0	6.7	13.3	16.7	17.2	3.3	9.6
150	20.0	16.7	16.7	16.7	6.7	6.7	10.3	16.7	14.4
180	6.7	10.0	10.0	10.0	6.7	10.0	6.9	6.7	8.2
210	13.3	16.7	20.0	23.3	23.3	23.3	27.6	23.3	22.1
240	20.0	13.3	10.0	6.7	20.0	10.0	6.9	13.3	12.7
270	.0	6.7	6.7	6.7	.0	.0	3.4	3.3	2.5
300	10.0	6.7	3.3	6.7	3.3	3.3	3.4	3.3	4.9
330	.0	3.3	.0	3.3	6.7	6.7	3.4	3.3	4.2
360	10.0	6.7	13.3	6.7	6.7	10.0	10.3	13.3	8.9
Calm	.0	.0	.0	.0	.0	.0	.0	.0	.0
Nobs	(30)	(30)	(30)	(30)	(30)	(30)	(29)	(30)	(716)
Average wind m/s	6.4	6.4	6.2	6.8	6.7	6.3	5.9	6.2	6.4

DISTRIBUTION OF WINDSPEED WITH WIND DIRECTIONS (%)

Class I: Windspeed .4 - 2.0 m/s
Class II: Windspeed 2.1 - 4.0 m/s
Class III: Windspeed 4.1 - 6.0 m/s
Class IV: Windspeed > 6.0 m/s

*) Wind-direction	Classes I	II	III	IV	Total	Nobs	Average wind m/s
30	.4	1.5	1.3	2.2	5.4	(39)	5.1
60	.6	2.7	2.2	.3	5.7	(41)	3.9
90	.1	.7	.1	.3	1.3	(9)	3.9
120	.0	2.2	3.5	3.9	9.6	(69)	5.8
150	.4	2.7	6.6	4.7	14.4	(103)	5.3
180	.1	1.4	3.2	3.5	8.2	(59)	5.6
210	.3	1.5	7.3	13.0	22.1	(158)	7.3
240	.3	1.4	6.1	4.9	12.7	(91)	5.9
270	.4	.3	.1	1.7	2.5	(18)	5.7
300	.0	.0	.1	4.7	4.9	(35)	8.9
330	.3	.7	1.0	2.2	4.2	(30)	7.4
360	.0	1.4	2.1	5.4	8.9	(64)	8.5
Calm					.0	(0)	
Total	2.9	16.5	33.7	46.9	100.0	(716)	
Average wind m/s	1.6	3.2	5.0	8.7			6.4

*) This number indicates central direction of sector

Table B2, cont.

Station : VIKSJØFJELL
Period : 01.10.90 - 31.10.90

DIURNAL VARIATION OF WIND DIRECTIONS (%)

*) Wind-direction	Hours 01	04	07	10	13	16	19	22	Wind-rose
30	3.2	.0	.0	.0	3.2	3.2	3.2	.0	1.6
60	6.5	6.5	3.2	.0	3.2	.0	3.2	3.2	3.4
90	.0	.0	6.5	6.5	.0	.0	.0	.0	.9
120	3.2	6.5	.0	3.2	3.2	.0	3.2	3.2	3.2
150	6.5	9.7	12.9	9.7	6.5	12.9	9.7	6.5	9.8
180	9.7	9.7	12.9	16.1	19.4	22.6	19.4	12.9	13.8
210	19.4	19.4	16.1	16.1	16.1	12.9	16.1	22.6	17.3
240	25.8	29.0	22.6	19.4	19.4	16.1	19.4	29.0	23.1
270	16.1	3.2	12.9	6.5	3.2	12.9	12.9	9.7	9.9
300	.0	12.9	3.2	19.4	22.6	9.7	6.5	.0	8.6
330	9.7	.0	6.5	3.2	3.2	9.7	6.5	6.5	5.5
360	.0	3.2	3.2	.0	.0	.0	.0	6.5	2.7
Calm	.0	.0	.0	.0	.0	.0	.0	.0	.0
Nobs	(31)	(31)	(31)	(31)	(31)	(31)	(31)	(31)	(744)
Average wind m/s	8.2	7.7	8.4	8.5	8.2	8.1	8.1	8.2	8.2

DISTRIBUTION OF WINDSPEED WITH WIND DIRECTIONS (%)

Class I: Windspeed .4 - 2.0 m/s
Class II: Windspeed 2.1 - 4.0 m/s
Class III: Windspeed 4.1 - 6.0 m/s
Class IV: Windspeed > 6.0 m/s

*) Wind-direction	Classes I	II	III	IV	Total	Nobs	Average wind m/s
30	.1	.9	.3	.3	1.6	(12)	4.1
60	.7	.7	.9	1.1	3.4	(25)	4.7
90	.0	.5	.4	.0	.9	(7)	3.4
120	.4	1.1	1.1	.7	3.2	(24)	4.4
150	.3	1.1	2.6	5.9	9.8	(73)	7.6
180	.5	1.1	2.7	9.5	13.8	(103)	7.4
210	.0	.9	2.7	13.7	17.3	(129)	9.0
240	.3	1.9	2.7	18.3	23.1	(172)	9.2
270	.0	.8	2.3	6.9	9.9	(74)	8.5
300	.0	.0	1.7	6.9	8.6	(64)	9.1
330	.1	.5	.8	4.0	5.5	(41)	8.5
360	.0	.3	.9	1.5	2.7	(20)	8.7
Calm					.0	(0)	
Total	2.4	9.8	19.1	68.7	100.0	(744)	
Average wind m/s	1.6	3.0	5.1	10.0			8.2

*) This number indicates central direction of sector

Table B2, cont.

Station : VIKSJØFJELL
Period : 01.11.90 - 30.11.90

DIURNAL VARIATION OF WIND DIRECTIONS (%)

*) Wind-direction	Hours 01	04	07	10	13	16	19	22	Wind-rose
30	3.8	.0	.0	.0	.0	.0	.0	.0	.7
60	3.8	4.0	.0	4.3	.0	.0	4.2	.0	1.4
90	3.8	8.0	16.0	13.0	8.7	12.5	8.3	12.5	12.2
120	7.7	8.0	.0	4.3	4.3	4.2	4.2	4.2	3.6
150	.0	4.0	8.0	8.7	13.0	8.3	.0	.0	4.8
180	11.5	4.0	.0	.0	.0	4.2	8.3	4.2	4.3
210	3.8	4.0	12.0	8.7	8.7	4.2	8.3	12.5	7.8
240	38.5	32.0	32.0	21.7	21.7	20.8	20.8	20.8	25.2
270	7.7	4.0	12.0	17.4	13.0	20.8	29.2	25.0	16.7
300	11.5	12.0	4.0	8.7	17.4	16.7	8.3	12.5	10.9
330	3.8	12.0	16.0	13.0	8.7	4.2	4.2	8.3	9.1
360	3.8	8.0	.0	.0	4.3	4.2	4.2	.0	3.3
Calm	.0	.0	.0	.0	.0	.0	.0	.0	.0
Nobs	(26)	(25)	(25)	(23)	(23)	(24)	(24)	(24)	(580)
Average wind m/s	6.5	6.3	6.4	6.7	6.6	7.0	7.2	6.9	6.7

DISTRIBUTION OF WINDSPEED WITH WIND DIRECTIONS (%)

Class I: Windspeed .4 - 2.0 m/s
Class II: Windspeed 2.1 - 4.0 m/s
Class III: Windspeed 4.1 - 6.0 m/s
Class IV: Windspeed > 6.0 m/s

*) Wind-direction	Classes I	II	III	IV	Total	Nobs	Average wind m/s
30	.0	.7	.0	.0	.7	(4)	3.1
60	.5	.7	.0	.2	1.4	(8)	3.1
90	1.0	5.0	3.3	2.9	12.2	(71)	4.5
120	.5	2.1	.7	.3	3.6	(21)	3.5
150	.0	3.3	1.6	.0	4.8	(28)	3.7
180	1.0	2.2	.3	.7	4.3	(25)	3.3
210	.9	.7	.9	5.3	7.8	(45)	7.9
240	1.0	9.0	7.4	7.8	25.2	(146)	6.0
270	1.9	4.0	1.9	9.0	16.7	(97)	6.8
300	.2	1.2	1.2	8.3	10.9	(63)	10.0
330	.5	.5	.5	7.6	9.1	(53)	10.5
360	.0	.3	.7	2.2	3.3	(19)	10.0
Calm					.0	(0)	
Total	7.6	29.7	18.4	44.3	100.0	(580)	
Average wind m/s	1.6	3.0	4.9	10.8			6.7

*) This number indicates central direction of sector

Table B2, cont.

Station : VIKSJØFJELL
Period : 01.01.91 - 31.01.91

DIURNAL VARIATION OF WIND DIRECTIONS (%)

*) Wind-direction	Hours 01	04	07	10	13	16	19	22	Wind-rose
30	.0	.0	.0	.0	.0	.0	.0	.0	.6
60	.0	7.1	.0	7.1	14.3	6.3	6.7	6.7	4.8
90	7.7	.0	.0	.0	.0	.0	.0	.0	1.4
120	.0	.0	7.1	.0	7.1	.0	.0	.0	2.3
150	.0	7.1	.0	7.1	.0	6.3	6.7	.0	2.8
180	.0	7.1	7.1	7.1	.0	.0	6.7	6.7	4.0
210	7.7	21.4	14.3	21.4	21.4	25.0	.0	6.7	15.1
240	61.5	28.6	50.0	28.6	35.7	43.8	60.0	66.7	47.0
270	15.4	14.3	21.4	28.6	21.4	12.5	13.3	6.7	16.0
300	.0	14.3	.0	.0	.0	.0	.0	.0	2.8
330	7.7	.0	.0	.0	.0	.0	.0	6.7	1.7
360	.0	.0	.0	.0	.0	6.3	6.7	.0	1.4
Calm	.0	.0	.0	.0	.0	.0	.0	.0	.0
Nobs	(13)	(14)	(14)	(14)	(14)	(16)	(15)	(15)	(351)
Average wind m/s	10.3	9.6	9.6	10.8	10.9	11.6	10.9	9.9	10.4

DISTRIBUTION OF WINDSPEED WITH WIND DIRECTIONS (%)

Class I: Windspeed .4 - 2.0 m/s
Class II: Windspeed 2.1 - 4.0 m/s
Class III: Windspeed 4.1 - 6.0 m/s
Class IV: Windspeed > 6.0 m/s

*) Wind-direction	Classes I	II	III	IV	Total	Nobs	Average wind m/s
30	.0	.0	.0	.6	.6	(2)	8.9
60	.3	.3	.3	4.0	4.8	(17)	7.3
90	.0	.0	.6	.9	1.4	(5)	7.1
120	.0	.3	1.4	.6	2.3	(8)	5.3
150	.0	.9	1.7	.3	2.8	(10)	4.7
180	.0	.9	.0	3.1	4.0	(14)	9.5
210	.6	.9	1.4	12.3	15.1	(53)	12.4
240	.0	4.6	2.3	40.2	47.0	(165)	10.0
270	.0	1.4	.6	14.0	16.0	(56)	13.0
300	.0	.3	.3	2.3	2.8	(10)	11.9
330	.3	.0	.0	1.4	1.7	(6)	9.5
360	.0	.0	.0	1.4	1.4	(5)	10.8
Calm					.0	(0)	
Total	1.1	9.4	8.5	80.9	100.0	(351)	
Average wind m/s	1.5	3.2	4.8	12.0			10.4

*) This number indicates central direction of sector

Table B2, cont.

Station : VIKSJØFJELL
Period : 01.02.91 - 28.02.91

DIURNAL VARIATION OF WIND DIRECTIONS (%)

*) Wind-direction	Hours 01	04	07	10	13	16	19	22	Wind-rose
30	.0	4.2	.0	.0	.0	.0	.0	.0	1.0
60	8.0	4.2	4.2	4.0	.0	4.0	4.0	8.0	4.7
90	8.0	8.3	4.2	.0	8.0	4.0	.0	.0	3.0
120	.0	.0	4.2	4.0	.0	.0	4.0	.0	2.5
150	4.0	.0	4.2	4.0	.0	.0	.0	8.0	1.8
180	.0	4.2	4.2	4.0	8.0	4.0	8.0	4.0	5.9
210	16.0	12.5	20.8	20.0	16.0	16.0	12.0	8.0	14.1
240	52.0	54.2	45.8	48.0	52.0	52.0	52.0	56.0	51.6
270	4.0	8.3	8.3	8.0	8.0	12.0	12.0	4.0	7.4
300	.0	.0	.0	.0	.0	.0	.0	4.0	1.5
330	8.0	4.2	4.2	4.0	4.0	4.0	8.0	4.0	5.5
360	.0	.0	.0	4.0	4.0	4.0	.0	4.0	1.0
Calm	.0	.0	.0	.0	.0	.0	.0	.0	.0
Nobs	(25)	(24)	(24)	(25)	(25)	(25)	(25)	(25)	(597)
Average wind m/s	8.0	7.8	7.3	7.4	7.5	8.1	7.9	7.9	7.8

DISTRIBUTION OF WINDSPEED WITH WIND DIRECTIONS (%)

Class I: Windspeed .4 - 2.0 m/s
Class II: Windspeed 2.1 - 4.0 m/s
Class III: Windspeed 4.1 - 6.0 m/s
Class IV: Windspeed > 6.0 m/s

*) Wind-direction	Classes I	II	III	IV	Total	Nobs	Average wind m/s
30	.3	.5	.2	.0	1.0	(6)	2.8
60	.8	1.7	1.5	.7	4.7	(28)	4.0
90	.7	2.3	.0	.0	3.0	(18)	2.5
120	1.0	1.3	.2	.0	2.5	(15)	2.6
150	.8	1.0	.0	.0	1.8	(11)	2.2
180	.3	2.3	.8	2.3	5.9	(35)	6.3
210	.0	.7	1.8	11.6	14.1	(84)	8.7
240	.0	.8	6.0	44.7	51.6	(308)	8.7
270	.0	.0	1.7	5.7	7.4	(44)	7.3
300	.0	.0	.5	1.0	1.5	(9)	7.7
330	.0	.7	.2	4.7	5.5	(33)	10.7
360	.3	.7	.0	.0	1.0	(6)	2.7
Calm					.0	(0)	
Total	4.4	12.1	12.9	70.7	100.0	(597)	
Average wind m/s	1.6	3.1	5.1	9.4			7.8

*) This number indicates central direction of sector

Table B2, cont.

Station : VIKSJØFJELL
Period : 01.03.91 - 31.03.91

DIURNAL VARIATION OF WIND DIRECTIONS (%)

*) Wind-direction	Hours 01	04	07	10	13	16	19	22	Wind-rose
30	.0	3.2	.0	.0	.0	.0	.0	.0	.4
60	.0	.0	6.5	9.7	6.5	3.2	9.7	3.2	4.8
90	6.5	3.2	3.2	.0	.0	6.5	3.2	3.2	3.4
120	9.7	6.5	9.7	6.5	9.7	9.7	6.5	6.5	8.9
150	12.9	12.9	9.7	16.1	9.7	9.7	12.9	16.1	11.3
180	6.5	9.7	12.9	9.7	6.5	9.7	9.7	6.5	9.4
210	12.9	16.1	9.7	6.5	19.4	9.7	12.9	19.4	13.2
240	32.3	32.3	35.5	45.2	32.3	38.7	35.5	29.0	34.1
270	12.9	6.5	6.5	3.2	9.7	3.2	.0	3.2	6.7
300	3.2	3.2	.0	.0	.0	.0	3.2	6.5	2.0
330	.0	.0	.0	.0	3.2	9.7	3.2	6.5	1.5
360	3.2	3.2	3.2	3.2	3.2	.0	3.2	.0	3.2
Calm	.0	3.2	3.2	.0	.0	.0	.0	.0	1.1
Nobs	(31)	(31)	(31)	(31)	(31)	(31)	(31)	(31)	(744)
Average wind m/s	6.9	7.2	7.5	7.4	7.4	7.1	6.9	6.7	7.1

DISTRIBUTION OF WINDSPEED WITH WIND DIRECTIONS (%)

Class I: Windspeed .4 - 2.0 m/s
Class II: Windspeed 2.1 - 4.0 m/s
Class III: Windspeed 4.1 - 6.0 m/s
Class IV: Windspeed > 6.0 m/s

*) Wind-direction	Classes I	II	III	IV	Total	Nobs	Average wind m/s
30	.1	.0	.3	.0	.4	(3)	4.0
60	.5	1.5	1.3	1.5	4.8	(36)	5.0
90	.3	.8	1.5	.8	3.4	(25)	5.2
120	.1	.9	2.6	5.2	8.9	(66)	6.6
150	.8	1.3	2.6	6.6	11.3	(84)	7.0
180	.8	2.7	.7	5.2	9.4	(70)	6.7
210	1.1	2.3	.8	9.0	13.2	(98)	7.2
240	.8	4.7	8.1	20.6	34.1	(254)	7.6
270	.1	1.5	1.9	3.2	6.7	(50)	6.7
300	.0	.3	.4	1.3	2.0	(15)	6.5
330	.0	.3	.1	1.1	1.5	(11)	9.4
360	.1	.1	.1	2.8	3.2	(24)	13.8
Calm					1.1	(8)	
Total	4.8	16.4	20.3	57.4	100.0	(744)	
Average wind m/s	1.5	3.0	5.1	9.7			7.1

*) This number indicates central direction of sector

Table B2, cont.

Station : VIKSJØFJELL
Period : 01.04.91 - 30.04.91

DIURNAL VARIATION OF WIND DIRECTIONS (%)

*) Wind-direction	Hours 01	04	07	10	13	16	19	22	Wind-rose
30	6.7	.0	6.7	6.9	6.9	.0	3.3	3.3	4.4
60	.0	.0	.0	.0	3.4	6.9	3.3	.0	1.3
90	.0	.0	.0	3.4	.0	3.4	3.3	.0	1.4
120	.0	3.3	3.3	.0	3.4	3.4	3.3	6.7	2.7
150	10.0	.0	3.3	6.9	6.9	3.4	6.7	6.7	5.1
180	13.3	16.7	13.3	10.3	13.8	13.8	13.3	13.3	15.0
210	23.3	33.3	43.3	37.9	27.6	31.0	30.0	36.7	33.2
240	26.7	20.0	10.0	13.8	10.3	17.2	23.3	16.7	16.3
270	.0	3.3	6.7	6.9	3.4	3.4	.0	3.3	3.7
300	3.3	3.3	6.7	6.9	13.8	6.9	3.3	10.0	6.2
330	6.7	6.7	6.7	3.4	6.9	10.3	10.0	3.3	7.3
360	10.0	13.3	.0	3.4	.0	.0	.0	.0	3.2
Calm	.0	.0	.0	.0	3.4	.0	.0	.0	.3
Nobs	(30)	(30)	(30)	(29)	(29)	(29)	(30)	(30)	(711)
Average wind m/s	7.2	7.7	7.6	7.4	7.1	6.7	6.5	7.1	7.2

DISTRIBUTION OF WINDSPEED WITH WIND DIRECTIONS (%)

Class I: Windspeed .4 - 2.0 m/s
Class II: Windspeed 2.1 - 4.0 m/s
Class III: Windspeed 4.1 - 6.0 m/s
Class IV: Windspeed > 6.0 m/s

*) Wind-direction	Classes I	II	III	IV	Total	Nobs	Average wind m/s
30	.6	1.0	1.8	1.0	4.4	(31)	4.8
60	.1	.3	.7	.1	1.3	(9)	4.6
90	.0	.8	.6	.0	1.4	(10)	4.0
120	.4	.4	.6	1.3	2.7	(19)	5.1
150	.3	.1	.0	4.6	5.1	(36)	8.3
180	.6	1.1	.8	12.5	15.0	(107)	8.6
210	1.1	2.4	3.0	26.7	33.2	(236)	9.1
240	1.0	4.2	3.1	8.0	16.3	(116)	6.9
270	1.1	1.4	.6	.6	3.7	(26)	3.7
300	.6	3.1	2.0	.6	6.2	(44)	3.7
330	1.0	1.7	2.8	1.8	7.3	(52)	4.6
360	.7	.7	.8	1.0	3.2	(23)	4.7
Calm					.3	(2)	
Total	7.5	17.3	16.7	58.2	100.0	(711)	
Average wind m/s	1.3	3.0	5.1	9.8			7.2

*) This number indicates central direction of sector

Table B2, cont.

Station : VIKSJØFJELL
Period : 01.05.91 - 31.05.91

DIURNAL VARIATION OF WIND DIRECTIONS (%)

*) Wind-direction	Hours 01	04	07	10	13	16	19	22	Wind-rose
30	12.9	6.5	9.7	16.1	19.4	9.7	9.7	12.9	10.9
60	3.2	6.5	6.5	.0	3.2	9.7	6.5	6.5	5.9
90	9.7	6.5	6.5	9.7	12.9	9.7	9.7	3.2	7.8
120	.0	9.7	19.4	6.5	6.5	6.5	3.2	6.5	7.5
150	6.5	6.5	9.7	6.5	9.7	.0	6.5	9.7	7.7
180	16.1	9.7	3.2	16.1	12.9	12.9	12.9	9.7	12.4
210	9.7	9.7	9.7	6.5	9.7	12.9	12.9	9.7	9.7
240	12.9	16.1	9.7	12.9	.0	3.2	.0	6.5	7.4
270	9.7	19.4	9.7	9.7	12.9	9.7	6.5	3.2	9.3
300	12.9	3.2	6.5	3.2	3.2	3.2	9.7	16.1	7.0
330	6.5	3.2	6.5	3.2	6.5	12.9	6.5	16.1	8.2
360	.0	3.2	3.2	9.7	3.2	9.7	16.1	.0	6.3
Calm	.0	.0	.0	.0	.0	.0	.0	.0	.0
Nobs	(31)	(31)	(31)	(31)	(31)	(31)	(31)	(31)	(744)
Average wind m/s	4.7	4.6	5.3	5.9	6.1	5.8	5.2	4.9	5.3

DISTRIBUTION OF WINDSPEED WITH WIND DIRECTIONS (%)

Class I: Windspeed .4 - 2.0 m/s
Class II: Windspeed 2.1 - 4.0 m/s
Class III: Windspeed 4.1 - 6.0 m/s
Class IV: Windspeed > 6.0 m/s

*) Wind-direction	Classes I	II	III	IV	Total	Nobs	Average wind m/s
30	.3	3.4	4.6	2.7	10.9	(81)	4.9
60	.1	4.3	1.1	.4	5.9	(44)	3.7
90	.4	4.2	3.0	.3	7.8	(58)	3.8
120	.7	3.4	3.4	.1	7.5	(56)	3.9
150	.1	4.2	2.4	.9	7.7	(57)	4.3
180	.0	2.8	4.8	4.7	12.4	(92)	5.3
210	.1	2.2	3.6	3.8	9.7	(72)	5.6
240	.3	1.7	1.3	4.0	7.4	(55)	6.3
270	.3	.5	2.4	6.0	9.3	(69)	7.6
300	.5	1.7	2.2	2.6	7.0	(52)	5.7
330	.5	2.6	1.3	3.8	8.2	(61)	5.7
360	.1	1.9	1.5	2.8	6.3	(47)	6.9
Calm					.0	(0)	
Total	3.5	32.8	31.6	32.1	100.0	(744)	
Average wind m/s	1.5	3.2	5.0	8.3			5.3

*) This number indicates central direction of sector

APPENDIX C

Table C1: Equation constants for calculations of monthly mass loss steel vs. SO_2 in air, dry deposition Cl and time of wetness at Viksjøfjell.

Mass Loss Steel = $(A_1 + A_2 * C_{SO_2} + A_3 * C_{Cl}) * TOW$.

Test site: Viksjøfjell.

Period: 8/90-11/90, 2/91-4/91 (7 numbers of observations).

Rh >80%	A_1	A_2	A_3	R-sq.
TOW: T> -2.0	-0.261	0.00878	0.0001	0.786
TOW: T> -4.0	-0.156	0.00767	0.000035	0.963
TOW: T> -6.0	-0.0728	0.00566	0.00001	0.810

Table C2: Corrosion rate of steel (g/m^2*h) at Noatun, Sov1, Svanvik and Kobbfoss for the period 6/90, 7-8/90, 9/90-5/91.

Period	TOW Rh >80% T> -4°C	Noatun			Sov1		
		SO_2 µg/m³	ML steel g/m²	Cor. rate g/m²*h	SO_2 µg/m³	ML steel g/m²	Cor. rate g/m²*h
6/90	268	7.0	7.2	0.027	13.0	4.8	0.018
7/90-8/90	783	5.0	29.8	0.038	6.5	24.2	0.031
9/90-5/91	1366	6.0	41.0	0.030	10.3	64.0	0.047

Period	TOW Rh >80% T> -4°C	Svanvik			Kobbfoss		
		SO_2 µg/m³	ML steel g/m²	Cor. rate g/m²*h	SO_2 µg/m³	ML steel g/m²	Cor. rate g/m²*h
6/90	268	12.0	5.1	0.019	14.0	6.7	0.025
7/90-8/90	783	11.5	34.9	0.045	4.5	37.3	0.048
9/90-5/91	1366	13.4	68.0	0.050			

Mass loss (7-8/90) = Mass loss (6-8/90) - Mass loss (6/90)

Mass loss (9/90-5/91) = Mass loss (6/90-5/91) - Mass loss (6-8/90)

APPENDIX D

The effect of low concentration of sulphur dioxide
in the air on the atmospheric corrosion rate of MA2-1 alloy

The purpose of the investigations was to determine the sensitivity threshold of MA2-1 alloy (0.03% Cu, 0.41% Mn, 0.02% Si, 1.05% Zn, 0.0014% Ni, 0.02% Fe, 4.46% Al, Mg - remainder) corrosion to the concentration of sulphur dioxide in a real atmosphere. Such investigations were carried out during 2 years on the Zvenigorod corrosion station. In terms of the current classification of corrosion aggressiveness of atmosphere the Zvenigorod station is referred to as rural regions. However, on the territory of the site and in its vicinity (a radius of 1 km) there were point sources of sulphur dioxide (heat systems of 5 individual houses). The peak concentrations of sulphur dioxide in the atmosphere of the site during the heating period did not exceed 30-35 $\mu g/m^3$.

EXPERIMENTAL PROCEDURE

The samples were exposed in series of 5-10 samples in jalousie house during 15 days. Some series of the samples were tested during 30-45 days. In the course of the exposure the time of wetness of the metal surface (Rh > 80%) and the ambient temperature were measured using a summing device. The concentration of SO_2 was determined using the absorption method (by pumping the air through solution).

Corrosion was determined according to the mass losses. The corrosion rate was calculated per one hour of wetness.

EXPERIMENTAL RESULTS

Figure D1a characterizes the change in the concentration of SO_2 in the air during the experiment. The background concentration of SO_2 (possibly, also of other sulphur compounds) in the atmosphere of the site may be taken to be 8-10 $\mu g/m^3$. In the heating period (November-April) the concentration of SO_2 increases reaching the peak values of 30-35 $\mu g/m^3$ in December-February.

The corrosion rate of the alloy MA2-1 correlates well with the change in the concentration of SO_2. Figure D1b shows the change in the corrosion rate of the alloy MA2-1 in the same period. Even if low ambient temperature in winter months are not taken into account, a good synchronization of the curves a and b is observed.

The cross-section of curves a and b in different seasons of tests allows the dependence of the corrosion rate on the concentration of SO_2 to be obtained. As is shown in Figure D2, regardless of the large spread of the experimental points, the increase in the corrosion rate of MA2-1 is observed when the concentration of SO_2 above 10-15 $\mu g/m^3$. At the concentration of SO_2 ~ 20 $\mu g/m^3$ the metal corrosion increases 2-5 fold.

CONCLUSION

Is has been shown during continuous atmospheric corrosion tests, that the sensitivity threshold of the corrosion rate of the MA2-1 alloy to the concentration of SO_2 lies at 10-15 $\mu g/m^3$. The possibility to use corrosion effects for the control of the atmospheric SO_2 pollution has been shown.

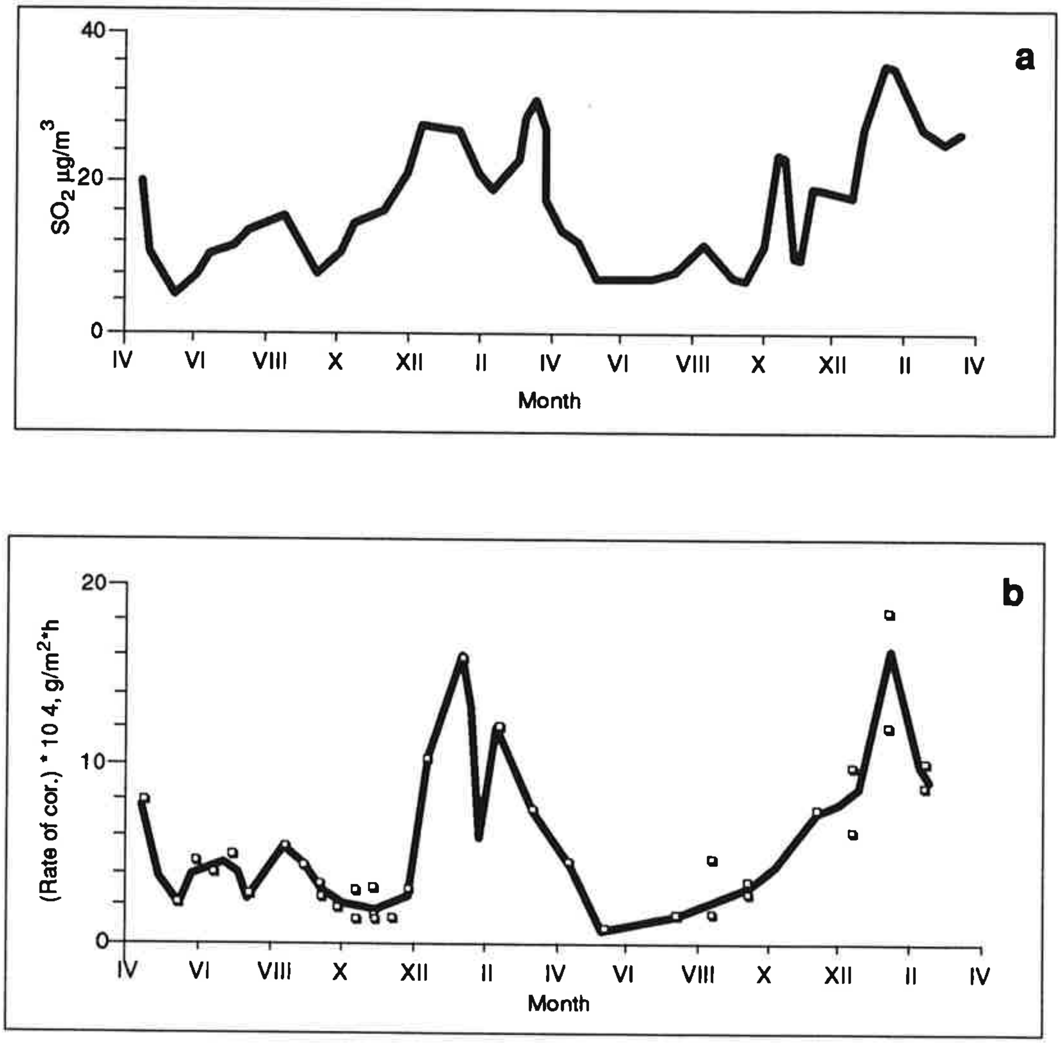

Figure D1: The kinetics of the change in SO_2 level (a) and rate of corrosion of MA2-1 alloy in jalousie house (b) at the Zvenigorod corrosion station.

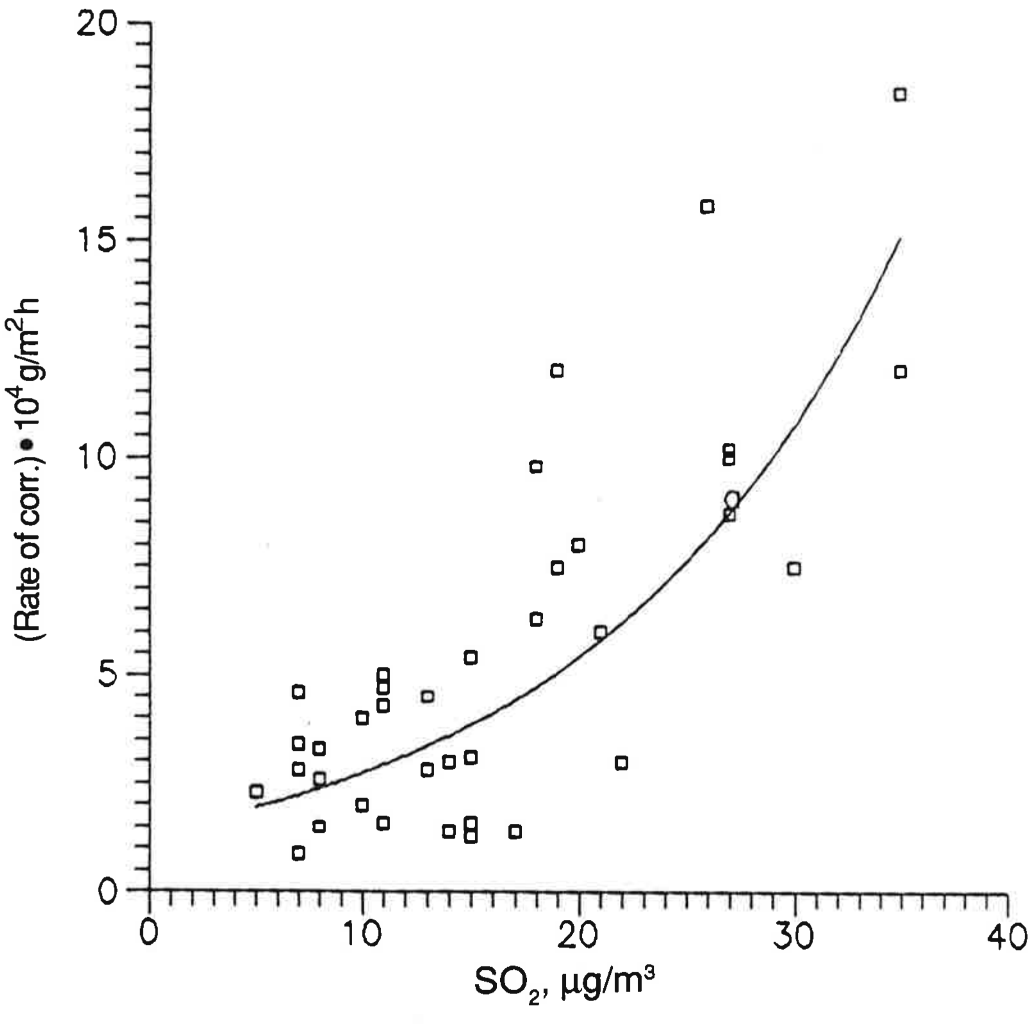

Figure D2: Rate of corrosion of MA2-1 alloy in a ventilated screen housing at the Zvenigorod corrosion station vs. concentration of SO_2 in air.

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TITLE
ABSTRACT

A bilateral exposure programme has been carried out along the Norwegian-Russian border. The aim has been to perform a qualitative evaluation of the effect of sulphur pollutants on the atmospheric corrosion in subarctic climate. The corrosion of steel was shown to be best described by equations which combined the effect of SO_2 and the time of wetness. A system for determining the limit target SO_2 level is described.

* Kategorier: Åpen - kan bestilles fra NILU A
Må bestilles gjennom oppdragsgiver B
Kan ikke utleveres C