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Author: A.G. Ritchie

Year: 1985"

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Keywords: Uranium - 6% niobium alloy
Corrosion
K10

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WIN 48F

THE ATMOSPHERIC CORROSION OF URANIUM - 6% NIOBIUM ALLOY

by

A G Ritchie, R C Greenwood, S J Randles, D R Netherton and Miss J Whitehorn

SUMMARY

Measurements of the kinetics of the corrosion of uranium - 6 weight % niobium alloy in moist atmospheres have been made. The alloy was tested in 2 forms: heat-treated (single phase, α'') and not-heat-treated (2 phases, α and γ). The heat-treated alloy was extremely resistant to corrosion, in agreement with the literature. The not-heat-treated alloy was much less resistant to corrosion, though still more resistant than unalloyed uranium. At temperatures up to 100°C, the heat-treated alloy produced less than 0.01 std cc H₂/cm² in moist nitrogen. This quantity did not increase with time, even in tests of several hundred or even thousands of hours. In moist air, the reaction was very slow, about 1/500 of the rate for unalloyed uranium. The not-heat-treated alloy reacted in moist nitrogen at about 1/5 of the rate of unalloyed uranium and at about 1/20 - 1/200 times the rate of unalloyed uranium in moist air. Comparison with US WR material showed that our heat-treated material showed the same corrosion resistance. K10 sometimes reduced the rate of corrosion of the alloy. On electrochemical grounds, it would be expected to be a corrosion inhibitor.

To obtain high corrosion resistance, it is clearly essentially for the uranium-niobium alloy to be in the α'' phase (heat-treated condition) for which the reaction rates are so low that a large unplated surface would react more slowly than an unalloyed uranium surface which was largely nickel plated but which had a few percent of its area unplated. However failure to achieve the correct heat-treatment such that the mixed ($\alpha + \gamma$) phase material was present, would give inferior performance to a largely nickel-plated unalloyed uranium surface.

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Approved for issue:

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November 1985

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1. INTRODUCTION

The published literature on the atmospheric corrosion of uranium - 6% niobium alloy is very limited.⁽¹⁻⁶⁾ The available literature on the corrosion of all uranium - niobium alloys in both moist air and moist nitrogen has been reviewed but the only conclusion that can be drawn is that these alloys are very corrosion resistant and that the corrosion resistance increases with niobium content.⁽⁷⁾ Preliminary experimental work at AWRE has already been reported⁽⁸⁾ and this is included here for completeness. A subsequent note detailing further progress has also been written⁽⁹⁾.

The atmospheric corrosion of uranium - 6% niobium alloy has been investigated using a variety of techniques:

- (a) weighing at intervals for samples stored in air under controlled conditions of temperature and humidity,
 - (b) gas analyses for samples stored in moist nitrogen to measure hydrogen evolution,
 - (c) continuous measurements of weight gain using a recording microbalance for samples exposed to moist nitrogen
- and
- (d) continuous measurements of pressure increase of samples exposed to water vapour at elevated temperatures.

2. EXPERIMENTAL

2.1 Materials

2.1.1 Uranium - 6% niobium (U-6Nb) alloy samples

The samples used for the earlier experiments described in this report all came from the same original piece of metal (serial number 3023-01-8688) which was a disc 12" diameter x $\frac{5}{8}$ " thick. This was cut into coupons 4" x $\frac{5}{8}$ " or $\frac{1}{2}$ " x $\frac{5}{8}$ " at ROF Cardiff. Because of the possibility that the metal could be anisotropic, samples cut from the disc in different directions were labelled with the direction of cut. Chemical analysis showed the following: Nb 5.91%, C 80 ppm, Fe 55 ppm, H 2, 1.9, 0.3 ppm (repeat analyses), O 160 ppm, N < 10 ppm⁽¹⁰⁾.

The metal as originally supplied was not in the required phase. To rectify this, some of the coupons were heat treated by R W Bacon (Metallurgy Division). The heat treatment consisted of heating in vacuo to 850°C, holding at 850°C for $\frac{3}{4}$ hour, and then quenching in silicone oil⁽¹⁰⁾. Both heat-treated (HT) and not-heat-treated (NHT) samples were used in the corrosion tests in order to determine if the heat treatment had any effect on the corrosion rate. X-ray diffraction analysis has shown that the NHT metal contains both α and γ phases while HT metal is in the α " phase⁽¹¹⁾.

HT samples were cleaned before corrosion tests by electropolishing in a sulphuric/phosphoric acid bath (1:1:1 conc H₂SO₄ : conc H₃PO₄ : H₂O). This readily removed the thin oxide layer formed during heating in a poor vacuum during the heat treatment process. The NHT samples had little visible corrosion product on them when they were received so they were simply cleaned in acetone and then in Inhibisol (1, 1, 1 trichloroethane) before use. Attempts to electropolish these samples failed, a black layer being formed rather than a shiny surface.

Later experiments used US WR grade material. Coupons were cut from a piece of WR grade uranium-niobium alloy (serial no. 3031-00-5069) at ROF Cardiff. These experiments were done to check that the heat-treated (HT) material did behave like the WR grade metal to which it should be equivalent. These samples were also electropolished before corrosion testing.

2.1.2 Humidity Solutions

Saturated solutions of CaCl_2 , MgCl_2 and NaCl were used to provide constant humidity atmospheres for the gravimetric and gas analysis experiments. CaCl_2 and NaCl solutions give almost constant relative humidities (RH) of 17 - 19% RH (CaCl_2) and 74 - 75% RH (NaCl) over the temperature ranges 50 - 110°C (12). However, the humidity over saturated MgCl_2 solutions varies from 32% RH at 50°C to 19% RH at 110°C (12, 13).

2.2 Experimental Procedures

Four different techniques were used to monitor the extent of reaction: each is described separately below.

2.2.1 Gravimetric Studies in Moist Air

The procedure adopted was to store the samples in glass tubes in desiccators containing saturated salt solution to provide constant humidity atmospheres. The desiccators were placed in ovens and the samples were weighed at appropriate intervals, according to temperature. As the reaction proceeded, in some cases oxide spalled off the samples and was retained in the glass tubes. To avoid condensation on cold metal surfaces when the samples were put into warm moist atmospheres, the samples were preheated to the temperature of the test before being put into the controlled atmospheres. This method is the same as that recently used for the study of the corrosion of unalloyed uranium in moist air (14). However, saturated salt solutions are much less satisfactory at the higher temperature needed to measure the corrosion of a corrosion-resistant alloy.

2.2.2 Gas Analysis Studies in Moist Nitrogen

In these experiments, the uranium-niobium alloy samples were stored in glass cells in ovens and the atmospheres in the cells were analysed at intervals for hydrogen content using gas chromatography. Perkin-Elmer models F33 or 8310 or Pye Unicam model 204 gas chromatographs were used. The chromatography column was molecular sieve (5A) held at temperatures between 70 and 110°C using an argon carrier gas. The bottom part of the cells (below the side arm) was filled with a saturated salt solution to provide constant relative humidity. The uranium-niobium alloy samples were put in small beakers in the cells, resting on plastic discs which fitted just above the waist of the cell. The design of the cells is illustrated in Figure 1. Some of the later experiments used cells in which the greased ground glass taps were replaced by greaseless Rotaflow taps. After loading the cells with salt solution and with the samples, the cells were connected to a vacuum line and evacuated to remove air and to outgas the salt solution. The cells were then filled with nitrogen to a known pressure, removed from the vacuum line and put into the oven. Cells were sampled at intervals, according to temperature. It was necessary to sample the cells at reasonably frequent intervals to make sure that a dangerous pressure of hydrogen had not built up. The gas chromatographic analysis could detect oxygen, nitrogen and hydrogen. The nitrogen was used as an internal standard and the hydrogen and oxygen contents were calculated relative to the nitrogen. The nitrogen content was measured when the cell was filled on the vacuum line and allowances were made for the quantity of nitrogen removed at each sampling. The oxygen content was

useful as an indicator of any leaks. Normally there was a blank value equivalent to 2-3 std cc of oxygen in the cell due to the small dead space in the syringe and the gas injector of the chromatograph. Oxygen contents in excess of this were regarded as indicative of leaks.

A number of samples were treated with K10 liquid (dinitro-/trinitro-ethyl benzene mixture) before being put on corrosion test. The treatment consisted of immersing the uranium-niobium alloy in the K10 for a period, removing the alloy from the K10 and then wiping excess K10 off the sample with a tissue. These samples were then put on corrosion test in the usual way.

2.2.3 Continuous Weight Gain Measurements in Moist Nitrogen

The uranium-niobium alloy sample was exposed to a moist nitrogen atmosphere and the sample weight was continuously recorded using a recording microbalance. The microbalance was a Mark 2 vacuum microbalance with Robal control unit (C I Electronics, Salisbury). A diagram of the microbalance system is shown in Figure 2. The essential parts of the system were a 2-stage gas saturator, a reaction tube inside a furnace, the gas mixing tube and the balance head. The balance head was flushed with dry nitrogen to prevent condensation of water on the balance beam or on the suspension wire. The dry gas in the balance head and the moist gas from the reaction tube mixed in the mixing tube and passed out of the balance system together. The water vapour pressure was controlled by varying the temperature of the gas saturator. Salt solutions were not used with the microbalance.

2.2.4 Hydrogen Pressure Measurements for Reaction in Water Vapour

In these experiments, the uranium alloy sample was put in a tube inside a furnace. Water vapour was supplied from an external reservoir. The water reservoir was always slightly below room temperature to avoid condensation of water in the tubing. The extent of reaction was measured by following hydrogen pressure increase using a transducer. A diagram of the apparatus is shown in Figure 3.

3. RESULTS

3.1 Uranium-niobium alloy/oxygen/water vapour reaction

The weight gains for the various samples are listed in Tables 1 - 23 for the temperatures 50, 80, 91, 102 and 110°C. The results are summarised in Table 24. It will be seen that some samples showed changes in reaction rate as corrosion proceeded. In order to calculate initial or final rates, points outside the appropriate region of the weight gain plot were given zero weights when calculating least squares fits. At 50°C, no detectable weight gains were found in 5 months. At 80°C, the weight gains were at most 0.26 mg/cm² in 15 months. At 91°C, the weight gains were not more than 1.06 mg/cm² in 19 months for not-heat-treated samples and 0.23 mg/cm² for heat-treated samples. The exception was sample Nb 46X which reacted very rapidly at one corner, but then the reaction slowed to a rate much closer to that of the other samples. At 100°C, weight gains were typically 2 mg/cm² in 6 months (4000h). At 110°C, weight gains were 5 mg/cm² in about 3 months (2000 h). The weight gains are plotted for 80, 91, 102 and 110°C in Figures 4-7. The lines drawn are averages of the best fit lines for the individual samples. These average values are listed in Table 24.

There are clear differences in behaviour between the HT and NHT as is evident from Figures 4-6. Although initially the HT samples gained weight only slightly more slowly than the NHT ones, after about 2000 h (3 months) at 102°C or about 6000 h (9 months) at 91°C the NHT samples started to gain weight at a much faster rate while the HT samples put on very little extra weight. At 110°C, NHT samples again showed an increase in rate of weight gain during the corrosion test, this time at around 1000 h (see Figure 7). The increases in reaction rate may have been due to condensation on the samples. Indeed for 2 samples at 102°C (Nb 1X and Nb 2X), yellow uranium trioxide was observed, indicating that condensation had occurred as UO_3 is formed only in the presence of both oxygen and liquid water⁽¹⁵⁾. The problem of condensation on the samples also occurred in previous work⁽¹⁴⁾ and in that case prevented any results being obtained for the uranium-oxygen-water vapour reaction at 102°C and 74% relative humidity. An alternative explanation for the apparent changes in reaction rates involving surface nucleation will be discussed fully in section 4.2.

In order to test the possibility that anisotropy of the material affected the reaction rates, samples cut in 2 perpendicular directions were tested. These are labelled with X or Y in the sample numbers. No systematic difference was found. Humidity did not seem to affect the reaction rate either. This agrees with previous results for the uranium-oxygen-water vapour reaction⁽¹⁴⁾.

Both the initial and final reaction rates for the not-heat-treated material from Table 24 (which mostly represent the linear reaction rates over only part of the reaction) are plotted according to the Arrhenius equation in Figure 8. There is considerable scatter of the experimental points, often due to the very low reaction rates which make accurate measurement difficult. Because of this and because of the small temperature range of the measurements an Arrhenius equation must be used with caution but the best fit equations were:

$$\text{NHT samples, initial rates: } k = 1.4 \times 10^{21} \exp(-37.5 \text{ kcal/RT}) \text{ } \mu\text{g/cm}^2/\text{h}$$

$$\text{NHT samples, final rates: } k = 9.9 \times 10^{28} \exp(-49.9 \text{ kcal/RT}) \text{ } \mu\text{g/cm}^2/\text{h}$$

$$\text{HT samples, initial rates: } k = 3.4 \times 10^{12} \exp(-23.9 \text{ kcal/RT}) \text{ } \mu\text{g/cm}^2/\text{h}$$

Moreover, if the interpretation of the initial rates in terms of nucleation is correct, the initial rates would not be expected to be linear so any apparent linear rate can be regarded only as an empirical fit.

3.2 Uranium-niobium Alloy/Water Vapour Reaction

3.2.1 Gas Analysis Results

The uranium-niobium alloy/water vapour reaction has been investigated at 60 - 100°C by gas analysis, at 90 - 150°C using a microbalance, and at 150 - 250°C by gas pressure measurements. The results for the gas analysis experiments are listed in Tables 25 - 29. It can be seen that hydrogen was produced in most of the experiments using NHT samples at 75°C or above. The exceptions were samples Nb 3, NbA, most of the samples treated with K10 and the samples at 60°C. Nb 3 had a high initial oxygen content, presumably due to an air leak during filling the cell. From experience with unalloyed

uranium, traces of oxygen would be expected to inhibit the uranium-water vapour reaction⁽¹⁵⁾. Most of the 60°C samples were in cells which had high oxygen levels, which probably accounts for their lack of reactivity. Sample Nb A was on test for only 42 h. With the exception of sample K 1, KH and KF none of the NHT samples treated with K10 produced any significant amount of hydrogen. Hydrogen evolution curves for those samples which produced significant amounts of hydrogen are plotted in Figure 9 (for samples at 75 - 93°C) and Figure 10 (for samples at 100°C). To allow for different humidities, all measurements of hydrogen evolved were divided by the square roots of the water vapour pressures used, on the assumption that the reaction rate shows such a humidity dependence, as is the case for unalloyed uranium⁽¹⁶⁾. It can be seen that there is an initial period in which the reaction rate increases until a final steady rate is reached. The rates quoted in Tables 25 and 26 are the final linear rates. Too few points were obtained in the linear region for it to be worthwhile performing least squares fits, so the curves were drawn by eye. It can be seen that the 2 samples at 75°C (Nb 5 and Nb R) have very similar gradients once the effect of the different humidities (74% RH for Nb 5 and 18% RH for Nb R) has been allowed for, showing good agreement between different samples if it is assumed that the square root dependence on water vapour applies to U-6Nb alloy as well as to unalloyed uranium. The samples at 90 - 93°C generally show good agreement with each other. The results at 100°C (Figure 10) show more variation between individual samples. This may be due to variable amounts of condensation on the samples. In previous experiments on the uranium-oxygen-water vapour reaction⁽¹⁴⁾ it was found to be impossible to prevent condensation on uranium samples at 100°C and 74% relative humidity so the same problem may be occurring here, particularly for those experiments at 74% RH (Nb 6 and K 1). The direction of cut of the samples had no noticeable effect on the corrosion rate.

The HT samples (with or without K10) produced so little hydrogen that no hydrogen evolution rates can be derived. Most of the HT samples produced very small amounts of hydrogen (<0.01 std cc H₂/cm²) fairly soon after being put on test but this hydrogen level did not increase in many hundreds or even thousands of hours. The only exception was sample Nb 7 which produced 0.47 std cc H₂/cm² in 136½ h. However this sample was tested under the most vigorous conditions (100°C and 74% RH) and other samples at this temperature behaved normally.

3.2.2 Microbalance Results

The microbalance experiments showed a linear rate of weight gain for NHT uranium-niobium alloy samples in moist nitrogen. This is illustrated in Figure 11. The linear rates of weight gain are listed in Table 30. The measured reaction rates at various humidities at 110°C have been plotted against the square root of water vapour pressure in Figure 12. A reasonable straight line is obtained, the maximum deviation from the straight line being less than 10% of the measured rate. This confirms the water vapour pressure dependence of the gas analysis results. The rates of weight gain corrected for water vapour pressure dependence are plotted according to the Arrhenius equation in Figure 13. For comparison, the gas analysis results have been converted to the equivalent weight gains using the equation:



and these have been plotted with the weight gains from the microbalance experiments. It can be seen that there is reasonable agreement between the hydrogen evolution and the weight gain measurements, though the hydrogen evolution measurements give higher reaction rates at 100°C, probably due

to condensation. The equation for the line drawn in Figure 13 to give a good fit through the microbalance results is:

$$k = 8.2 \times 10^5 p_{\text{H}_2\text{O}}^{\frac{1}{2}} \exp(-9.5 \text{ kcal/RT}) \mu\text{g/cm}^2/\text{h}, p_{\text{H}_2\text{O}} \text{ in torr} \dots\dots\dots (2)$$

It is in reasonable agreement with the gas analysis results, bearing the experimental scatter in mind.

Two microbalance experiments using a heat-treated sample showed no detectable weight gains. In the first experiment, no weight gain occurred in 16 h at 150°C at a water vapour pressure of 152 torr. The temperature was increased to 180°C, then to 200°C and then left at 250°C for 67 h. No detectable weight gain was found even at these temperatures. In the second experiment, the same piece of heat-treated uranium-niobium alloy was exposed to the same water vapour pressure at 250°C for 20 h and again no detectable weight increase occurred.

3.2.1 Gas Pressure Measurements

The results for the hydrogen pressure measurement experiments are listed in Table 31. The experimental pressure measurements have been converted to the equivalent weight gains for comparison with the microbalance experiments. The agreement for the not-heat-treated (NHT) samples is good. The heat-treated (HT) sample reacted at a very low rate, even at 250°C, in agreement with gas analysis experiments showing negligible reaction.

4. DISCUSSION

4.1 Uranium-niobium Alloy/Water Vapour Reaction

(a) NHT Samples

The rate of corrosion of the NHT samples in moist nitrogen has been measured using a recording microbalance, gas analysis techniques and hydrogen pressure. The results using the 3 techniques are in reasonable agreement with each other (see Figure 13). The reaction rate is proportional to the square root of the water vapour pressure, in agreement with results for the uranium-water vapour reaction⁽¹⁶⁾. The rate equation is:

$$k_{\text{U Nb}} = 8.2 \times 10^5 p_{\text{H}_2\text{O}}^{\frac{1}{2}} \exp(-9.5 \text{ kcal/RT}) \mu\text{g wt gain/cm}^2/\text{h}, \\ p_{\text{H}_2\text{O}} \text{ in torr} \dots\dots\dots (3)$$

This compares with the rate equation for unalloyed uranium:

$$k_{\text{U}} = 1.75 \times 10^6 p_{\text{H}_2\text{O}}^{\frac{1}{2}} \exp(-9.0 \text{ kcal/RT}) \mu\text{g wt gain/cm}^2/\text{h}, \\ p_{\text{H}_2\text{O}} \text{ in torr} \dots\dots\dots (4)$$

The rates of reaction of uranium and NHT uranium-niobium alloy with water vapour are compared in Table 32. It can be seen that uranium reacts about 5 times faster than the alloy. The water vapour pressures illustrated (4 and 16 torr) correspond to approximately 20 and 80% RH at 20°C.

The NHT niobium alloy samples which had been treated with K10 generally produced insignificant amounts of hydrogen. Samples K1, KF and KH were exceptions and reacted at similar rates to samples not treated with K10.

The simplest explanation for the lack of reactivity of the other samples which had been treated with K10 is that, after treatment, a thin film of K10 remained on the metal surface. K10 is an oily substance and a thin oily film may just have protected the metal against attack by water vapour. An alternative explanation is electrochemical. Electrochemical studies⁽¹⁷⁾ have shown that nitrobenzene and o-dinitrobenzene inhibit the aqueous corrosion of uranium. As K10 contains dinitro- and trinitro-benzene, it is chemically very similar to those compounds which are known corrosion inhibitors.

(b) HT Samples

The heat-treated samples produced only negligible amounts of hydrogen under conditions where the not-heat-treated samples produced considerable amounts. Clearly the reactivity of the HT material is much lower than that of the NHT material and so it is much more difficult to establish quantitative reaction rates. The marked difference in reactivity between the HT and the NHT materials is presumably related to the phases of the metal present. The heat-treated material consists of a single phase (α'') while the not-heat-treated material consists of 2 phases (α and γ). The α phase contains very little niobium (<0.5 weight % Nb⁽¹⁸⁾) and so a reaction rate not markedly less than for the unalloyed material is not surprising. K10 did not dramatically affect the reaction rate for the heat-treated material but the reaction rate is so slow anyway that only a sharp acceleration in rate as a result of K10 treatment would have been noticeable. The difference between HT and NHT alloys has been reported previously in the difference between cast and quenched alloys^(2, 4, 7). The quenched alloys were much more corrosion-resistant than the cast alloys.

4.2 Uranium-niobium Alloy/Oxygen/Water Vapour Reaction

4.2.1 General Discussion

The rates of oxidation of uranium-niobium alloy in moist air are clearly much slower than for uranium and there is sharp difference in the behaviour of the heat-treated and the not-heat-treated samples. While the HT samples oxidised only slightly slower than the NHT samples initially, after a period the NHT samples started to react much more rapidly while the HT samples continued to react slowly or even stopped reacting. Over long time periods, the difference between the 2 materials would become progressively more marked. It is possible that in some cases the acceleration in rate of the oxidation of the NHT alloy may be due to condensation on the samples and subsequent change in mechanism, resulting in the formation of yellow uranium trioxide. This obviously does not occur with the heat-treated samples. There does not appear to be any significant dependence of reaction rate on relative humidity, in agreement with experience for unalloyed uranium^(14, 15, 19). An alternative and probably more likely explanation for the increase in reaction rates is the nucleation of increasing numbers of reacting sites on the surface of the samples. It is of course possible that there are 2 genuine linear rates with a sharp transition between them but it seems more likely that there is a gradual increase in rate as more sites are

nucleated until the whole sample is reacting uniformly and a constant reaction rate (linear weight gain plot) is established. According to this explanation, only the final reaction rate is meaningful and any initial rate can be regarded only as an empirical fit to the experimental points. The details of the mathematics are described in Appendix A and the fitting procedure is described in Appendix B.

The experimental results at 80°C are still in the initial stages so no fit is possible according to the nucleation theory. At 91°C, the experimental results clearly indicate an increasing reaction rate followed by a constant rate (see Figure 14). Samples Nb 41X and Nb 42Y fit the Avrami equation well; Nb 44X behaved strangely, initially putting on weight rapidly, then losing weight and finally increasing weight again. If the anomalous region of its weight gain curve is ignored, it fits the Avrami equation well. The final linear rates for all these samples are very similar. At 102°C, samples Nb 1X, Nb 1Y, Nb 3X, Nb 3Y agree very closely with each other for the first 2000 h (see Figure 15). Consequently the weight gains for all these samples have been used together in a fit to the Avrami equation. A good fit is obtained. After 2000 h, sharp jumps in the weight occurred and the weight gain could not be fitted to a smooth curve. Samples Nb 2X and Nb 2Y agreed well with each other and, in this case also, a single fit to the Avrami equation was obtained for both samples. At 110°C, the 3 samples Nb 21X, Nb 21Y and K2 agreed well with each other so a single fit to the Avrami equation was obtained (see Figure 15). The fitting parameters for the Avrami fits are listed in Table 33. The parameter k is equivalent to a final linear rate constant, while the expression $\frac{1}{2}k\alpha$ is a rate constant for the initial quadratic stage. It can be seen that there is reasonable agreement between the different samples at each temperature without any systematic dependence on humidity. Too much weight should not be given to the actual values of the parameters as in some cases it is possible to obtain almost equally good fits with quite a wide range of values for the parameters.

4.2.2 Summary of Results

The oxidation rates for both HT and NHT uranium-niobium alloy in moist air are compared with those for uranium in Tables 34 and 35. The reaction rates for uranium are calculated from the equation⁽¹⁴⁾:-

$$k_u = 6.0 \times 10^{16} \exp(-26.3 \text{ kcal/RT}) \mu\text{g weight gain/cm}^2/\text{h} \dots (5)$$

It can be seen that uranium oxidises about 60-300 times faster than the NHT niobium alloy in the initial stages, or about 500 times faster than the HT alloy. In the later stages, uranium reacts 20-200 times faster than the NHT alloy while the HT alloy reacts very slowly. Comparisons of performance of these alloys with unalloyed uranium which is largely nickel-plated but with a small area unplated must be tempered by considerations of total surface area reacting. This reveals that the unplated NHT alloy might offer only a marginal improvement over a largely plated unalloyed specimen of the same total surface area.

5. CONCLUSIONS

Uranium-niobium alloy reacts with both water vapour and moist air more slowly than uranium. The heat-treated(HT) alloy is much more resistant to corrosion than the not-heat-treated (NHT) alloy, which is only moderately resistant. The rate of reaction of the NHT alloy with water vapour is given by the equation:-

$$k_{\text{UNb}} = 8.2 \times 10^5 p_{\text{H}_2\text{O}}^{\frac{1}{2}} \exp (-9.5 \text{ kcal/RT}) \mu\text{g weight gain/cm}^2/\text{h},$$

$p_{\text{H}_2\text{O}}$ in torr

The HT alloy reacted with water vapour so slowly that it has not been possible to derive an equation for the corrosion rate. Except for one sample (Nb 7), less than 0.01 std cc H_2/cm^2 was produced in tests lasting hundreds or thousands of hours at up to 100°C.

HT and NHT samples behaved differently in moist air. Although initially the HT samples reacted only slightly more slowly than the NHT ones, after a while the NHT samples increased their corrosion rates while the HT samples continued reacting only slowly or even stopped reacting.

US WR material showed negligible reaction with water vapour, as found for UK heat-treated (HT) samples, which should be equivalent to the US material.

K10 sometimes reduced the rate of corrosion of the alloy. On electrochemical grounds it would be expected to be a corrosion inhibitor.

The corrosion rates for the heat-treated material are so low that a large unplated surface would react more slowly than the same area of unalloyed uranium which was largely nickel-plated but which had a few percent of its area unplated. Failure to achieve the correct heat-treatment for the unplated alloy would offer little advantage over a largely plated unalloyed component.

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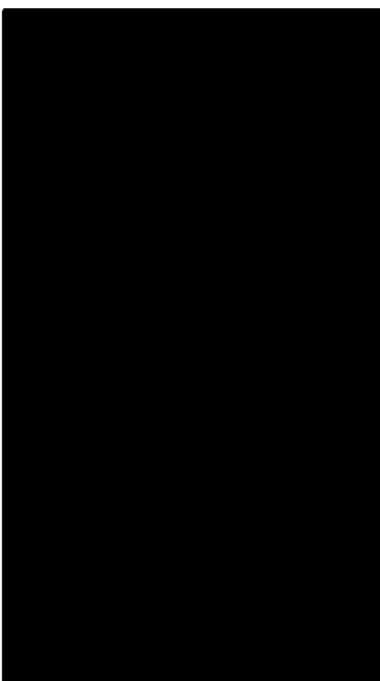


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APPENDIX A

EFFECT OF SURFACE NUCLEATION ON WEIGHT GAIN CURVES FOR URANIUM-NIOBIUM ALLOY/OXYGEN/WATER VAPOUR REACTION

Some samples apparently show 2 linear regions in plots of weight gain against time. Whilst it is possible that there are genuinely 2 linear rates with a sharp transition between them, it is more likely that there is in fact an initial period in which nucleation takes place followed by a final linear rate. With a little experimental scatter, the upward curvature of the initial period could be mistaken for an initial straight line. The rate of a nucleation reaction can be described by the Avrami eqⁿ (see eg C H Bamford and C F H Tipper⁽²⁰⁾). This leads to an equation with the general form:

$$\frac{dW}{dt} = k(1 - e^{-\alpha t^n})$$

where n is a small integer. In the simple case $n = 1$, an analytic solution can be obtained:

$$\begin{aligned} \frac{dW}{dt} &= k(1 - e^{-\alpha t}) \\ \therefore W &= k \left[t - \frac{e^{-\alpha t}}{-\alpha} \right]_0^t = k \left(t - \frac{1}{\alpha} [1 - e^{-\alpha t}] \right) \end{aligned}$$

For small t , $e^{-\alpha t} \approx 1 - \alpha t + \frac{\alpha^2 t^2}{2}$,

$$\therefore W \approx k \left(t - \frac{1}{\alpha} \left[1 - (1 - \alpha t + \frac{\alpha^2 t^2}{2} \dots) \right] \right) = \frac{1}{2} k \alpha t^2$$

ie in the initial stages, a quadratic equation should be obeyed, with rate constant $\frac{1}{2} k \alpha$.

For large t , $e^{-\alpha t} \ll 1$, $\therefore W \approx k \left(t - \frac{1}{\alpha} \right)$

The final equation is therefore linear and the gradients and intercepts of the final linear region can be used to obtain estimates for the parameters k and α . Further refinement of these parameters can be obtained by least squares fitting, as described in Appendix B. It may be noted that the factor $[1 - e^{-\alpha t}]$ can be regarded as the fraction of the sample surface which is reacting at time t . At large t , this factor tends to 1 and the entire surface of the sample is reacting uniformly and a linear weight gain plot is obtained.

An advantage of this method of fitting the experimental weight gain data is that only 2 parameters (k and α) are required while to fit 2 straight lines requires 4 parameters (gradients and intercepts for each straight line). It can be seen from the graphs for the Avrami fits (Figures 14 and 15) that better fits are obtained using the 2-parameter Avrami equation than for the 4-parameter straight line fits (see Figures 5-7).

APPENDIX B

LEAST SQUARES FITTING TO THE EQUATION: $W = k (t - \frac{1}{\alpha} [1 - e^{-\alpha t}])$

This equation is linear in the parameter k and non-linear in the parameter α . k can therefore be eliminated, leaving a non-linear equation in α only, which must be solved by iterative means. Following the normal procedure for least square fitting, the sum of squares is calculated and the parameters chosen to minimise the sum of squares.

$$\text{Sum of squares } S = \frac{1}{n} \sum_{i=1}^n (W(t_i) - W_i)^2 \quad \dots\dots\dots (1)$$

$$= \frac{1}{n} \sum_{i=1}^n (k(t_i - \frac{1}{\alpha} [1 - e^{-\alpha t_i}] - W_i)^2 \quad \dots\dots\dots (2)$$

where W_i is the weight of the sample at time t_i and $W(t_i)$ is the calculated weight of the sample using the fitting equation.

$$\text{For minimum, } \frac{\partial S}{\partial k} = \frac{\partial S}{\partial \alpha} = 0, \quad \dots\dots\dots (3)$$

$$\text{let } f(\alpha, t) = t - \frac{1}{\alpha} [1 - e^{-\alpha t}] \quad \dots\dots\dots (4)$$

$$\therefore W = kf(\alpha, t) \quad \dots\dots\dots (5)$$

$$\therefore \frac{\partial S}{\partial k} = \frac{2}{n} \sum_{i=1}^n (kf(\alpha, t_i) - W_i) \cdot f(\alpha, t_i) = 0 \quad \dots\dots\dots (6)$$

$$\frac{\partial S}{\partial \alpha} = \frac{2}{n} \sum_{i=1}^n (kf(\alpha, t_i) - W_i) \cdot k \frac{\partial f(\alpha, t_i)}{\partial \alpha} = 0 \quad \dots\dots\dots (7)$$

$$\text{from (6), } k = \frac{\sum_i W_i f(\alpha, t_i)}{\sum_i f^2(\alpha, t_i)} \quad \dots\dots\dots (8)$$

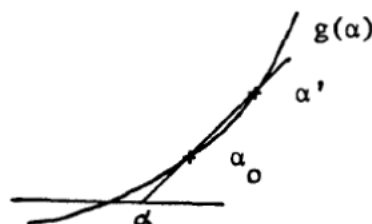
Let $g(\alpha) = \partial S / \partial \alpha$ and substitute for k from (8) into (6).

To avoid confusion in the subscripts, the letter j is used for subscripts from eqⁿ (8).

$$\therefore g(\alpha) = \sum_j \left(\frac{f(\alpha, t_j) \sum_i W_i f(\alpha, t_i)}{\sum_j f^2(\alpha, t_j)} - W_i \right) \frac{\partial f(\alpha, t_i)}{\partial \alpha} = 0 \quad \dots\dots\dots (9)$$

This is an equation in only one parameter α . k can be obtained by substitution of α in (8).

The optimum values for α can be obtained by a linear search. 2 trial values for α (α_0 and α')



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are chosen. $g(\alpha)$ is evaluated for these 2 values of α . Then by straight line extrapolation,

$$\frac{g(\alpha') - g(\alpha_0)}{\alpha' - \alpha_0} = \frac{g(\alpha_0)}{\alpha_0 - \alpha}$$

where α is the extrapolated value at which $g(\alpha)$ would be 0 if $g(\alpha)$ were a linear function of α .

$$\therefore \alpha = \alpha_0 - \frac{g(\alpha_0)(\alpha' - \alpha_0)}{g(\alpha') - g(\alpha_0)}$$

This simple method enables α to be calculated in a few iterations. The other parameter, k , is obtained by substitution for α into equation (8).

TABLE 1

URANIUM 6% NIOBIUM ALLOY/OXYGEN/WATER VAPOUR REACTION.

SAMPLE NUMBER=NB5X HT SURFACE TREATMENT=ELECTROPOLISHED.

TEMPERATURE OF TEST=50°C RELATIVE HUMIDITY OF TEST=75%

EXPOSURE TIME IN HOURS.	WEIGHT GAIN IN MG/CM2.	FIT OF POINT TO LINE.	ERROR OF POINT.	WEIGHT OF POINT.
0.0	0.00	0.00	0.00	1.00
4126.5	0.00	0.00	0.00	1.00

GRADIENT=0 INTERCEPT=0 STANDARD DEVIATION=0

SAMPLE NUMBER=NB5Y HT SURFACE TREATMENT=ELECTROPOLISHED.

TEMPERATURE OF TEST=50°C RELATIVE HUMIDITY OF TEST=75%

EXPOSURE TIME IN HOURS.	WEIGHT GAIN IN MG/CM2.	FIT OF POINT TO LINE.	ERROR OF POINT.	WEIGHT OF POINT.
0.0	0.00	0.00	0.00	1.00
4126.5	0.00	0.00	0.00	1.00

GRADIENT=0 INTERCEPT=0 STANDARD DEVIATION=0

SAMPLE NUMBER=NB6X SURFACE TREATMENT=INHIBISOL CLEANED.

TEMPERATURE OF TEST=50°C RELATIVE HUMIDITY OF TEST=75%

EXPOSURE TIME IN HOURS.	WEIGHT GAIN IN MG/CM2.	FIT OF POINT TO LINE.	ERROR OF POINT.	WEIGHT OF POINT.
0.0	0.00	0.00	0.00	1.00
4126.5	0.04	0.04	0.00	1.00

GRADIENT=1E-05 INTERCEPT=0 STANDARD DEVIATION=0

SAMPLE NUMBER=NB6Y SURFACE TREATMENT=INHIBISOL CLEANED.

TEMPERATURE OF TEST=50°C RELATIVE HUMIDITY OF TEST=75%

EXPOSURE TIME IN HOURS.	WEIGHT GAIN IN MG/CM2.	FIT OF POINT TO LINE.	ERROR OF POINT.	WEIGHT OF POINT.
0.0	0.00	0.00	0.00	1.00
4126.5	-0.01	-0.01	0.00	1.00

GRADIENT=-2E-06 INTERCEPT=0 STANDARD DEVIATION=0

SAMPLE NUMBER=NB7X HT SURFACE TREATMENT=ELECTROPOLISHED.

TEMPERATURE OF TEST=50°C RELATIVE HUMIDITY OF TEST=75%

EXPOSURE TIME IN HOURS.	WEIGHT GAIN IN MG/CM2.	FIT OF POINT TO LINE.	ERROR OF POINT.	WEIGHT OF POINT.
0.0	0.00	0.00	0.00	1.00
4126.5	-0.01	-0.01	0.00	1.00

GRADIENT=-2E-06 INTERCEPT=0 STANDARD DEVIATION=0

TABLE 2

SAMPLE NUMBER=NB7Y HT SURFACE TREATMENT=ELECTROPOLISHED.

TEMPERATURE OF TEST=50°C RELATIVE HUMIDITY OF TEST=32%

EXPOSURE TIME IN HOURS.	WEIGHT GAIN IN MG/CM2.	FIT OF POINT TO LINE.	ERROR OF POINT.	WEIGHT OF POINT.
0.0	0.00	0.00	0.00	1.00
4126.5	0.00	0.00	0.00	1.00

GRADIENT=0 INTERCEPT=0 STANDARD DEVIATION=0

 SAMPLE NUMBER=NB8X SURFACE TREATMENT=INHIBISOL CLEANED.

TEMPERATURE OF TEST=50°C RELATIVE HUMIDITY OF TEST=32%

EXPOSURE TIME IN HOURS.	WEIGHT GAIN IN MG/CM2.	FIT OF POINT TO LINE.	ERROR OF POINT.	WEIGHT OF POINT.
0.0	0.00	0.00	0.00	1.00
4126.5	0.00	0.00	0.00	1.00

GRADIENT=0 INTERCEPT=0 STANDARD DEVIATION=0

 SAMPLE NUMBER=NB8Y SURFACE TREATMENT=INHIBISOL CLEANED.

TEMPERATURE OF TEST=50°C RELATIVE HUMIDITY OF TEST=32%

EXPOSURE TIME IN HOURS.	WEIGHT GAIN IN MG/CM2.	FIT OF POINT TO LINE.	ERROR OF POINT.	WEIGHT OF POINT.
0.0	0.00	0.00	0.00	1.00
4126.5	-.04	-.04	0.00	1.00

GRADIENT=-1E-05 INTERCEPT=0 STANDARD DEVIATION=0

 SAMPLE NUMBER=NB9X HT SURFACE TREATMENT=ELECTROPOLISHED.

TEMPERATURE OF TEST=50°C RELATIVE HUMIDITY OF TEST=17%

EXPOSURE TIME IN HOURS.	WEIGHT GAIN IN MG/CM2.	FIT OF POINT TO LINE.	ERROR OF POINT.	WEIGHT OF POINT.
0.0	0.00	0.00	0.00	1.00
4126.5	-.01	-.01	0.00	1.00

GRADIENT=-2E-06 INTERCEPT=0 STANDARD DEVIATION=0

 SAMPLE NUMBER=NB9Y HT SURFACE TREATMENT=ELECTROPOLISHED.

TEMPERATURE OF TEST=50°C RELATIVE HUMIDITY OF TEST=17%

EXPOSURE TIME IN HOURS.	WEIGHT GAIN IN MG/CM2.	FIT OF POINT TO LINE.	ERROR OF POINT.	WEIGHT OF POINT.
0.0	0.00	0.00	0.00	1.00
4126.5	-.01	-.01	0.00	1.00

GRADIENT=-2E-06 INTERCEPT=0 STANDARD DEVIATION=0

TABLE 3

SAMPLE NUMBER=NB48AX HT SURFACE TREATMENT=INHIBISOL CLEANED

TEMPERATURE OF TEST=80°C RELATIVE HUMIDITY OF TEST=74%

EXPOSURE TIME IN HOURS.	WEIGHT GAIN IN MG/CM2.	FIT OF POINT TO LINE.	ERROR OF POINT.	WEIGHT OF POINT.
367.0	0.01	0.00	-.01	1.00
2112.0	0.02	0.02	0.00	1.00
2712.0	0.02	0.02	0.00	1.00
3485.5	0.02	0.03	0.01	1.00
4992.0	0.02	0.04	0.02	1.00
6286.0	0.07	0.05	-.02	1.00
7635.0	0.24	0.06	-.18	0.00
8808.0	0.08	0.07	-.01	1.00
10107.0	0.08	0.08	0.00	1.00
11141.0	0.08	0.09	0.01	1.00

GRADIENT=8E-06 INTERCEPT=1E-03 STANDARD DEVIATION=.0173

TABLE 4

SAMPLE NUMBER=NB49AX SURFACE TREATMENT=INHIBISOL CLEANED

TEMPERATURE OF TEST=80°C RELATIVE HUMIDITY OF TEST=74%

EXPOSURE TIME IN HOURS.	WEIGHT GAIN IN MG/CM2.	FIT OF POINT TO LINE.	ERROR OF POINT.	WEIGHT OF POINT.
1367.0	0.01	0.01	0.00	1.00
2112.0	0.02	0.02	0.00	1.00
2712.0	0.02	0.02	0.00	1.00
3485.5	0.02	0.03	0.01	1.00
4992.0	0.03	0.04	0.01	1.00
6286.0	0.07	0.05	-.02	1.00
7635.0	0.17	0.06	-.11	0.00
8808.0	0.08	0.07	-.01	1.00
10107.0	0.08	0.08	0.00	1.00
11141.0	0.09	0.09	0.00	1.00

GRADIENT=9E-06 INTERCEPT=-2E-03 STANDARD DEVIATION=.0129

TABLE 5

SAMPLE NUMBER=NB50AX HT SURFACE TREATMENT=INHIBISOL CLEANED
 TEMPERATURE OF TEST=80'C RELATIVE HUMIDITY OF TEST=27%

EXPOSURE TIME IN HOURS.	WEIGHT GAIN IN MG/CM2.	FIT OF POINT TO LINE.	ERROR OF POINT.	WEIGHT OF POINT.
367.0	0.02	0.03	0.01	1.00
2112.0	0.05	0.04	-.01	1.00
2712.0	0.05	0.05	0.00	1.00
3485.5	0.05	0.05	0.00	1.00
4992.0	0.05	0.06	0.01	1.00
6286.0	0.07	0.07	0.00	1.00
7635.0	0.10	0.07	-.03	1.00
8808.0	0.08	0.08	0.00	1.00
10107.0	0.26	0.09	-.17	0.00
11141.0	0.08	0.10	0.02	1.00

GRADIENT=6E-06 INTERCEPT=.03 STANDARD DEVIATION=.0182

TABLE 6

SAMPLE NUMBER=NB51AX SURFACE TREATMENT=INHIBISOL CLEANED
 TEMPERATURE OF TEST=80'C RELATIVE HUMIDITY OF TEST=27%

EXPOSURE TIME IN HOURS.	WEIGHT GAIN IN MG/CM2.	FIT OF POINT TO LINE.	ERROR OF POINT.	WEIGHT OF POINT.
1367.0	0.02	0.02	0.00	1.00
2112.0	0.04	0.03	-.01	1.00
2712.0	0.05	0.05	0.00	1.00
3485.5	0.05	0.06	0.01	1.00
4992.0	0.09	0.09	0.00	1.00
6286.0	0.12	0.12	0.00	1.00
7635.0	0.14	0.14	0.00	1.00
8808.0	0.15	0.16	0.01	1.00
10107.0	0.20	0.19	-.01	1.00
11141.0	0.21	0.21	0.00	1.00

GRADIENT=1.9E-05 INTERCEPT=-7E-03 STANDARD DEVIATION=.0113

TABLE 7

SAMPLE NUMBER=NB52AX HT SURFACE TREATMENT=INHIBISOL CLEANED

TEMPERATURE OF TEST=80'C RELATIVE HUMIDITY OF TEST=19%

EXPOSURE TIME IN HOURS.	WEIGHT GAIN IN MG/CM2.	FIT OF POINT TO LINE.	ERROR OF POINT.	WEIGHT OF POINT.
367.0	0.01	0.01	0.00	1.00
2112.0	0.02	0.02	0.00	1.00
2712.0	0.02	0.02	0.00	1.00
3485.5	0.02	0.03	0.01	1.00
4992.0	0.04	0.03	-.01	1.00
6286.0	0.05	0.04	-.01	1.00
7635.0	0.05	0.04	-.01	1.00
8808.0	0.05	0.05	0.00	1.00
10107.0	0.05	0.05	0.00	1.00
11141.0	0.05	0.06	0.01	1.00

GRADIENT=4E-06 INTERCEPT=.012 STANDARD DEVIATION=9.8E-03

TABLE 8

FINAL REACTION RATE

SAMPLE NUMBER=NB41X SURFACE TREATMENT=INHIBISOL CLEANED.

TEMPERATURE OF TEST=91'C RELATIVE HUMIDITY OF TEST=74%

EXPOSURE TIME IN HOURS.	WEIGHT GAIN IN MG/CM2.	FIT OF POINT TO LINE.	ERROR OF POINT.	WEIGHT OF POINT.
484.5	0.02	-.29	-.31	0.00
941.0	0.09	-.25	-.34	0.00
1277.5	0.05	-.22	-.27	0.00
1541.0	0.07	-.19	-.26	0.00
1973.0	0.07	-.15	-.22	0.00
2813.0	0.13	-.08	-.21	0.00
3628.0	0.13	0.00	-.13	0.00
5059.0	0.17	0.14	-.03	0.00
6072.0	0.24	0.23	-.01	1.00
6892.5	0.32	0.31	-.01	1.00
7285.0	0.33	0.35	0.02	1.00
8579.0	0.45	0.47	0.02	1.00
9928.0	0.68	0.59	-.09	1.00
11101.0	0.60	0.70	0.10	1.00
12400.0	0.80	0.83	0.03	1.00
13456.0	0.98	0.93	-.05	1.00

GRADIENT=9.4E-05 INTERCEPT=-.34 STANDARD DEVIATION=.0805

INITIAL REACTION RATE

SAMPLE NUMBER=NB41X SURFACE TREATMENT=INHIBISOL CLEANED.

TEMPERATURE OF TEST=91'C RELATIVE HUMIDITY OF TEST=74%

EXPOSURE TIME IN HOURS.	WEIGHT GAIN IN MG/CM2.	FIT OF POINT TO LINE.	ERROR OF POINT.	WEIGHT OF POINT.
484.5	0.02	0.04	0.02	1.00
941.0	0.09	0.05	-.04	1.00
1277.5	0.05	0.06	0.01	1.00
1541.0	0.07	0.07	0.00	1.00
1973.0	0.07	0.08	0.01	1.00
2813.0	0.13	0.11	-.02	1.00
3628.0	0.13	0.13	0.00	1.00
5059.0	0.17	0.18	0.01	1.00
6072.0	0.24	0.20	-.04	0.00
6892.5	0.32	0.23	-.09	0.00
7285.0	0.33	0.24	-.09	0.00
8579.0	0.45	0.28	-.17	0.00
9928.0	0.68	0.32	-.36	0.00
11101.0	0.60	0.35	-.25	0.00
12400.0	0.80	0.39	-.41	0.00
13456.0	0.98	0.42	-.56	0.00

GRADIENT=2.9E-05 INTERCEPT=.026 STANDARD DEVIATION=.0272

TABLE 9

FINAL REACTION RATE

SAMPLE NUMBER=NB42Y SURFACE TREATMENT=INHIBISOL CLEANED.

TEMPERATURE OF TEST=91'C RELATIVE HUMIDITY OF TEST=74%

EXPOSURE TIME IN HOURS.	WEIGHT GAIN IN MG/CM2.	FIT OF POINT TO LINE.	ERROR OF POINT.	WEIGHT OF POINT.
484.5	0.01	-.29	-.30	0.00
941.0	0.03	-.25	-.28	0.00
1277.5	0.01	-.22	-.23	0.00
1541.0	0.03	-.19	-.22	0.00
1973.0	0.03	-.15	-.18	0.00
2813.0	0.09	-.08	-.17	0.00
3628.0	0.08	0.00	-.08	0.00
5059.0	0.14	0.13	-.01	0.00
6072.0	0.21	0.23	0.02	1.00
6892.5	0.28	0.31	0.03	1.00
7285.0	0.36	0.34	-.02	1.00
8579.0	0.43	0.46	0.03	1.00
9928.0	0.79	0.59	-.20	1.00
11101.0	0.59	0.70	0.11	1.00
12400.0	0.77	0.82	0.05	1.00
13456.0	0.95	0.92	-.03	1.00

GRADIENT=9.4E-05 INTERCEPT=-.339 STANDARD DEVIATION=.1288

INITIAL REACTION RATE

SAMPLE NUMBER=NB42Y SURFACE TREATMENT=INHIBISOL CLEANED.

TEMPERATURE OF TEST=91'C RELATIVE HUMIDITY OF TEST=74%

EXPOSURE TIME IN HOURS.	WEIGHT GAIN IN MG/CM2.	FIT OF POINT TO LINE.	ERROR OF POINT.	WEIGHT OF POINT.
484.5	0.01	0.00	-.01	1.00
941.0	0.03	0.02	-.01	1.00
1277.5	0.01	0.03	0.02	1.00
1541.0	0.03	0.03	0.00	1.00
1973.0	0.03	0.05	0.02	1.00
2813.0	0.09	0.07	-.02	1.00
3628.0	0.08	0.09	0.01	1.00
5059.0	0.14	0.13	-.01	1.00
6072.0	0.21	0.16	-.05	0.00
6892.5	0.28	0.19	-.09	0.00
7285.0	0.36	0.20	-.16	0.00
8579.0	0.43	0.24	-.19	0.00
9928.0	0.79	0.27	-.52	0.00
11101.0	0.59	0.31	-.28	0.00
12400.0	0.77	0.35	-.42	0.00
13456.0	0.95	0.38	-.57	0.00

GRADIENT=2.9E-05 INTERCEPT=-.011 STANDARD DEVIATION=.0197

TABLE 10

SAMPLE NUMBER=NB43X HT SURFACE TREATMENT=ELECTROPOLISHED				
TEMPERATURE OF TEST=91'C RELATIVE HUMIDITY OF TEST=74%				
EXPOSURE TIME IN HOURS.	WEIGHT GAIN IN MG/CM2.	FIT OF POINT TO LINE.	ERROR OF POINT.	WEIGHT OF POINT.
484.5	0.02	-.01	-.03	1.00
941.0	0.04	0.00	-.04	1.00
1277.5	0.02	0.01	-.01	1.00
1541.0	0.05	0.01	-.04	1.00
1973.0	0.04	0.02	-.02	1.00
2813.0	0.02	0.04	0.02	1.00
3628.0	0.03	0.05	0.02	1.00
5059.0	0.03	0.08	0.05	1.00
6072.0	0.03	0.10	0.07	1.00
6892.5	0.05	0.12	0.07	1.00
7285.0	0.14	0.13	-.01	1.00
8579.0	0.13	0.15	0.02	1.00
9928.0	0.32	0.18	-.14	1.00
11101.0	0.09	0.20	0.11	1.00
12400.0	0.27	0.23	-.04	1.00
13456.0	0.29	0.25	-.04	1.00
GRADIENT=2E-05 INTERCEPT=-.017 STANDARD DEVIATION=.0882				
*****1				

TABLE 11

FINAL REACTION RATE

SAMPLE NUMBER=NB44X SURFACE TREATMENT=INHIBISOL CLEANED

TEMPERATURE OF TEST=91°C RELATIVE HUMIDITY OF TEST=26%

EXPOSURE TIME IN HOURS.	WEIGHT GAIN IN MG/CM2.	FIT OF POINT TO LINE.	ERROR OF POINT.	WEIGHT OF POINT.
484.5	0.04	-.20	-.24	0.00
941.0	0.22	-.15	-.37	0.00
1277.5	0.58	-.12	-.70	0.00
1541.0	0.56	-.10	-.66	0.00
1973.0	0.47	-.06	-.53	0.00
2813.0	0.48	0.02	-.46	0.00
3628.0	0.50	0.10	-.40	0.00
5059.0	0.53	0.24	-.29	0.00
6072.0	0.40	0.33	-.07	0.00
6892.5	0.41	0.41	0.00	1.00
7285.0	0.45	0.45	0.00	1.00
8579.0	0.56	0.57	0.01	1.00
9928.0	0.73	0.70	-.03	1.00
11101.0	0.79	0.81	0.02	1.00
12400.0	0.90	0.93	0.03	1.00
13456.0	1.06	1.03	-.03	1.00

GRADIENT=9.5E-05 INTERCEPT=-.244 STANDARD DEVIATION=.0329

INITIAL REACTION RATE

SAMPLE NUMBER=NB44X SURFACE TREATMENT=INHIBISOL CLEANED

TEMPERATURE OF TEST=91°C RELATIVE HUMIDITY OF TEST=26%

EXPOSURE TIME IN HOURS.	WEIGHT GAIN IN MG/CM2.	FIT OF POINT TO LINE.	ERROR OF POINT.	WEIGHT OF POINT.
484.5	0.04	0.34	0.30	1.00
941.0	0.22	0.36	0.14	1.00
1277.5	0.58	0.37	-.21	1.00
1541.0	0.56	0.38	-.18	1.00
1973.0	0.47	0.40	-.07	1.00
2813.0	0.48	0.43	-.05	1.00
3628.0	0.50	0.45	-.05	1.00
5059.0	0.53	0.50	-.03	1.00
6072.0	0.40	0.54	0.14	1.00
6892.5	0.41	0.57	0.16	0.00
7285.0	0.45	0.58	0.13	0.00
8579.0	0.56	0.63	0.07	0.00
9928.0	0.73	0.68	-.05	0.00
11101.0	0.79	0.72	-.07	0.00
12400.0	0.90	0.76	-.14	0.00
13456.0	1.06	0.80	-.26	0.00

GRADIENT=3.5E-05 INTERCEPT=.327 STANDARD DEVIATION=.2354

TABLE 12

SAMPLE NUMBER=NB45X HT SURFACE TREATMENT=ELECTROPOLISHED

TEMPERATURE OF TEST=91'C RELATIVE HUMIDITY OF TEST=26%

EXPOSURE TIME IN HOURS.	WEIGHT GAIN IN MG/CM2.	FIT OF POINT TO LINE.	ERROR OF POINT.	WEIGHT OF POINT.
484.5	0.02	0.14	0.12	0.00
941.0	0.11	0.14	0.03	0.00
1277.5	0.15	0.14	-.01	0.00
1541.0	0.16	0.14	-.02	1.00
1973.0	0.16	0.15	-.01	1.00
2813.0	0.16	0.15	-.01	1.00
3628.0	0.16	0.16	0.00	1.00
5059.0	0.16	0.17	0.01	1.00
6072.0	0.16	0.17	0.01	1.00
6892.5	0.16	0.18	0.02	1.00
7285.0	0.16	0.18	0.02	1.00
8579.0	0.16	0.19	0.03	1.00
9928.0	0.21	0.20	-.01	1.00
11101.0	0.23	0.21	-.02	1.00
12400.0	0.23	0.22	-.01	1.00
13456.0	0.23	0.22	-.01	1.00

GRADIENT=7E-06 INTERCEPT=.133 STANDARD DEVIATION=.0245

TABLE 13
FINAL REACTION RATE

SAMPLE NUMBER=NB46X SURFACE TREATMENT=INHIBISOL CLEANED.

TEMPERATURE OF TEST=91'C RELATIVE HUMIDITY OF TEST=19%

EXPOSURE TIME IN HOURS.	WEIGHT GAIN IN MG/CM2.	FIT OF POINT TO LINE.	ERROR OF POINT.	WEIGHT OF POINT.
484.5	-.08	1.28	1.36	0.00
941.0	-.07	1.33	1.40	0.00
1277.5	1.61	1.37	-.24	0.00
1541.0	1.68	1.40	-.28	0.00
1973.0	1.70	1.45	-.25	0.00
2813.0	1.76	1.55	-.21	0.00
3628.0	1.78	1.64	-.14	0.00
5059.0	1.87	1.81	-.06	0.00
6072.0	1.97	1.92	-.05	0.00
6892.5	2.03	2.02	-.01	1.00
7285.0	2.07	2.06	-.01	1.00
8579.0	2.19	2.21	0.02	1.00
9928.0	2.38	2.37	-.01	1.00
11101.0	2.49	2.51	0.02	1.00
12400.0	2.67	2.66	-.01	1.00
13456.0	2.78	2.78	0.00	1.00

GRADIENT=1.16E-04 INTERCEPT=1.22 STANDARD DEVIATION=.0204

INITIAL REACTION RATE

SAMPLE NUMBER=NB46X SURFACE TREATMENT=INHIBISOL CLEANED.

TEMPERATURE OF TEST=91'C RELATIVE HUMIDITY OF TEST=19%

EXPOSURE TIME IN HOURS.	WEIGHT GAIN IN MG/CM2.	FIT OF POINT TO LINE.	ERROR OF POINT.	WEIGHT OF POINT.
484.5	-.08	0.74	0.82	1.00
941.0	-.07	0.87	0.94	1.00
1277.5	1.61	0.97	-.64	1.00
1541.0	1.68	1.04	-.64	1.00
1973.0	1.70	1.17	-.53	1.00
2813.0	1.76	1.41	-.35	1.00
3628.0	1.78	1.64	-.14	1.00
5059.0	1.87	2.04	0.17	1.00
6072.0	1.97	2.33	0.36	1.00
6892.5	2.03	2.56	0.53	0.00
7285.0	2.07	2.68	0.61	0.00
8579.0	2.19	3.04	0.85	0.00
9928.0	2.38	3.43	1.05	0.00
11101.0	2.49	3.76	1.27	0.00
12400.0	2.67	4.13	1.46	0.00
13456.0	2.78	4.43	1.65	0.00

GRADIENT=2.84E-04 INTERCEPT=.607 STANDARD DEVIATION=.8693

TABLE 14

SAMPLE NUMBER=NB47X HT SURFACE TREATMENT=ELECTROPOLISHED.

TEMPERATURE OF TEST=91°C RELATIVE HUMIDITY OF TEST=19%

EXPOSURE TIME IN HOURS.	WEIGHT GAIN IN MG/CM2.	FIT OF POINT TO LINE.	ERROR OF POINT.	WEIGHT OF POINT.
484.5	0.02	0.03	0.01	1.00
941.0	0.02	0.03	0.01	1.00
1277.5	0.05	0.04	-.01	1.00
1541.0	0.18	0.04	-.14	0.00
1973.0	0.06	0.05	-.01	1.00
2813.0	0.06	0.06	0.00	1.00
3628.0	0.08	0.07	-.01	1.00
5059.0	0.09	0.08	-.01	1.00
6072.0	0.08	0.10	0.02	1.00
6892.5	0.08	0.10	0.02	1.00
7285.0	0.09	0.11	0.02	1.00
8579.0	0.11	0.13	0.02	1.00
9928.0	0.17	0.14	-.03	1.00
11101.0	0.17	0.16	-.01	1.00
12400.0	0.17	0.17	0.00	1.00
13456.0	0.09	0.18	0.09	0.00

GRADIENT=1.2E-05 INTERCEPT=.021 STANDARD DEVIATION=.0234

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TABLE 15

SAMPLE NUMBER=NB1X SURFACE TREATMENT=INHIBISOL CLEANED.

TEMPERATURE OF TEST=102°C RELATIVE HUMIDITY OF TEST=74%

EXPOSURE TIME IN HOURS.	WEIGHT GAIN IN MG/CM2.	FIT OF POINT TO LINE.	ERROR OF POINT.	WEIGHT OF POINT.
66.0	0.00	-.03	-.03	1.00
863.0	0.09	0.10	0.01	1.00
1391.0	0.15	0.18	-.03	1.00
1919.0	0.24	0.26	0.02	1.00
2687.0	0.41	0.38	-.03	1.00
2951.0	0.81	0.42	-.39	0.00
3785.0	1.71	0.55	-1.16	0.00
3864.0	1.95	0.56	-1.39	0.00
4127.5	10.17	0.60	-9.57	0.00

GRADIENT=1.54E-04 INTERCEPT=-.036 STANDARD DEVIATION=.0274

SAMPLE NUMBER=NB1Y SURFACE TREATMENT=INHIBISOL CLEANED.

TEMPERATURE OF TEST=102°C RELATIVE HUMIDITY OF TEST=74%

EXPOSURE TIME IN HOURS.	WEIGHT GAIN IN MG/CM2.	FIT OF POINT TO LINE.	ERROR OF POINT.	WEIGHT OF POINT.
66.0	0.01	-.02	-.03	1.00
863.0	0.07	0.09	0.02	1.00
1391.0	0.14	0.16	0.02	1.00
1919.0	0.23	0.23	0.00	1.00
2687.0	0.36	0.34	-.02	1.00
2951.0	0.79	0.37	-.42	0.00
3785.0	1.91	0.49	-1.42	0.00
3864.0	10.15	0.50	-9.65	0.00
4127.5	11.05	0.53	-10.52	0.00

GRADIENT=1.36E-04 INTERCEPT=-.026 STANDARD DEVIATION=.0236

SAMPLE NUMBER=NB10Y HT SURFACE TREATMENT=ELECTROPOLISHED.

TEMPERATURE OF TEST=102°C RELATIVE HUMIDITY OF TEST=74%

EXPOSURE TIME IN HOURS.	WEIGHT GAIN IN MG/CM2.	FIT OF POINT TO LINE.	ERROR OF POINT.	WEIGHT OF POINT.
336.0	0.03	0.02	-.01	1.00
864.0	0.03	0.05	0.02	1.00
1628.0	0.11	0.10	-.01	1.00
1896.0	0.11	0.12	0.01	1.00
2730.0	0.17	0.17	0.00	1.00
2807.0	0.17	0.17	0.00	0.00
3071.5	0.17	0.19	0.02	0.00
3646.5	0.17	0.23	0.06	0.00

GRADIENT=6.3E-05 INTERCEPT=-4E-03 STANDARD DEVIATION=.0141

TABLE 16

SAMPLE NUMBER=NBIX SURFACE TREATMENT=INHIBISOL CLEANED.

TEMPERATURE OF TEST=102°C RELATIVE HUMIDITY OF TEST=74%

EXPOSURE TIME IN HOURS.	WEIGHT GAIN IN MG/CM2.	FIT OF POINT TO LINE.	ERROR OF POINT.	WEIGHT OF POINT.
66.0	0.00	-2.60	-2.60	0.00
863.0	0.09	-1.66	-1.75	0.00
1391.0	0.15	-1.04	-1.19	0.00
1919.0	0.24	-.41	-.65	0.00
2687.0	0.41	0.49	0.08	0.00
2951.0	0.81	0.80	-.01	1.00
3785.0	1.71	1.79	0.08	1.00
3864.0	1.95	1.88	-.07	1.00
4127.5	10.17	2.19	-7.98	0.00

GRADIENT=1.19E-03 INTERCEPT=-2.676 STANDARD DEVIATION=.0682

SAMPLE NUMBER=NBIV SURFACE TREATMENT=INHIBISOL CLEANED.

TEMPERATURE OF TEST=102°C RELATIVE HUMIDITY OF TEST=74%

EXPOSURE TIME IN HOURS.	WEIGHT GAIN IN MG/CM2.	FIT OF POINT TO LINE.	ERROR OF POINT.	WEIGHT OF POINT.
66.0	0.01	-3.08	-3.09	0.00
863.0	0.07	-2.01	-2.08	0.00
1391.0	0.14	-1.30	-1.44	0.00
1919.0	0.23	-.60	-.83	0.00
2687.0	0.36	0.44	0.08	0.00
2951.0	0.79	0.79	0.00	1.00
3785.0	1.91	1.91	0.00	1.00
3864.0	10.15	2.02	-8.13	0.00
4127.5	11.05	2.37	-8.68	0.00

GRADIENT=1.043E-03 INTERCEPT=-3.173 STANDARD DEVIATION=0

TABLE 17

SAMPLE NUMBER=NB2X SURFACE TREATMENT=INHIBISOL CLEANED.

TEMPERATURE OF TEST=102°C RELATIVE HUMIDITY OF TEST=23%

EXPOSURE TIME IN HOURS.	WEIGHT GAIN IN MG/CM2.	FIT OF POINT TO LINE.	ERROR OF POINT.	WEIGHT OF POINT.
66.0	0.00	-.01	-.01	1.00
863.0	0.18	0.18	0.00	1.00
1391.0	0.28	0.31	0.03	1.00
1919.0	0.46	0.44	-.02	1.00
2687.0	1.03	0.62	-.41	0.00
2951.0	1.29	0.69	-.60	0.00
3785.0	1.68	0.89	-.79	0.00
3864.0	1.74	0.91	-.83	0.00
4127.5	1.86	0.97	-.89	0.00
4703.5	2.64	1.11	-1.53	0.00

GRADIENT=2.41E-04 INTERCEPT=-.026 STANDARD DEVIATION=.0217

SAMPLE NUMBER=NB2Y SURFACE TREATMENT=INHIBISOL CLEANED.

TEMPERATURE OF TEST=102°C RELATIVE HUMIDITY OF TEST=23%

EXPOSURE TIME IN HOURS.	WEIGHT GAIN IN MG/CM2.	FIT OF POINT TO LINE.	ERROR OF POINT.	WEIGHT OF POINT.
66.0	0.00	-.05	-.05	1.00
863.0	0.13	0.19	0.06	1.00
1391.0	0.34	0.35	0.01	1.00
1919.0	0.49	0.51	0.02	1.00
2687.0	0.75	0.74	-.01	1.00
2951.0	0.85	0.82	-.03	1.00
3785.0	1.29	1.08	-.21	0.00
3863.0	2.96	1.10	-1.86	0.00
4127.5	3.40	1.18	-2.22	0.00
4703.5	3.92	1.36	-2.56	0.00

GRADIENT=3.04E-04 INTERCEPT=-.074 STANDARD DEVIATION=.0396

TABLE 18

SAMPLE NUMBER=NB11X HT SURFACE TREATMENT=ELECTROPOLISHED.

TEMPERATURE OF TEST=102°C RELATIVE HUMIDITY OF TEST=23%

EXPOSURE TIME IN HOURS.	WEIGHT GAIN IN MG/CM ² .	FIT OF POINT TO LINE.	ERROR OF POINT.	WEIGHT OF POINT.
336.0	0.07	0.05	-.02	1.00
864.0	0.05	0.08	0.03	1.00
1896.0	0.17	0.16	-.01	1.00
2730.0	0.21	0.21	0.00	1.00
2807.0	0.22	0.22	0.00	1.00
3071.5	0.20	0.24	0.04	0.00
3646.5	0.20	0.28	0.08	0.00

GRADIENT=6.9E-05 INTERCEPT=.025 STANDARD DEVIATION=.023

SAMPLE NUMBER=NB11Y HT SURFACE TREATMENT=ELECTROPOLISHED.

TEMPERATURE OF TEST=102°C RELATIVE HUMIDITY OF TEST=23%

EXPOSURE TIME IN HOURS.	WEIGHT GAIN IN MG/CM ² .	FIT OF POINT TO LINE.	ERROR OF POINT.	WEIGHT OF POINT.
336.0	0.04	0.02	-.02	1.00
864.0	0.09	0.14	0.05	1.00
1896.0	0.41	0.35	-.06	1.00
2730.0	0.50	0.53	0.03	1.00
2807.0	0.50	0.54	0.04	0.00
3071.5	0.50	0.60	0.10	0.00
3646.5	0.50	0.72	0.22	0.00

GRADIENT=2.1E-04 INTERCEPT=-.046 STANDARD DEVIATION=.0473

TABLE 19

SAMPLE NUMBER=NB2X SURFACE TREATMENT=INHIBISOL CLEANED.

TEMPERATURE OF TEST=102'C RELATIVE HUMIDITY OF TEST=23%

EXPOSURE TIME IN HOURS.	WEIGHT GAIN IN MG/CM2.	FIT OF POINT TO LINE.	ERROR OF POINT.	WEIGHT OF POINT.
66.0	0.00	-.36	-.36	0.00
863.0	0.18	0.08	-.10	0.00
1391.0	0.28	0.37	0.09	0.00
1919.0	0.46	0.66	0.20	0.00
2687.0	1.03	1.08	0.05	1.00
2951.0	1.29	1.23	-.06	1.00
3785.0	1.68	1.69	0.01	1.00
3864.0	1.74	1.73	-.01	1.00
4127.5	1.86	1.87	0.01	1.00
4703.5	2.64	2.19	-.45	0.00

GRADIENT=5.51E-04 INTERCEPT=-.398 STANDARD DEVIATION=.0418

SAMPLE NUMBER=NB2Y SURFACE TREATMENT=INHIBISOL CLEANED.

TEMPERATURE OF TEST=102'C RELATIVE HUMIDITY OF TEST=23%

EXPOSURE TIME IN HOURS.	WEIGHT GAIN IN MG/CM2.	FIT OF POINT TO LINE.	ERROR OF POINT.	WEIGHT OF POINT.
66.0	0.00	-5.88	-5.88	0.00
863.0	0.13	-4.16	-4.29	0.00
1391.0	0.34	-3.01	-3.35	0.00
1919.0	0.49	-1.87	-2.36	0.00
2687.0	0.75	-.21	-.96	0.00
2951.0	0.85	0.36	-.49	0.00
3785.0	1.29	2.17	0.88	1.00
3863.0	2.96	2.34	-.62	1.00
4127.5	3.40	2.91	-.49	1.00
4703.5	3.92	4.16	0.24	1.00

GRADIENT=2.164E-03 INTERCEPT=-6.024 STANDARD DEVIATION=.6745

TABLE 20

SAMPLE NUMBER=NB3X SURFACE TREATMENT=INHIBISOL CLEANED.

TEMPERATURE OF TEST=102°C RELATIVE HUMIDITY OF TEST=19%

EXPOSURE TIME IN HOURS.	WEIGHT GAIN IN MG/CM2.	FIT OF POINT TO LINE.	ERROR OF POINT.	WEIGHT OF POINT.
66.0	-.02	-.03	-.01	1.00
863.0	0.04	0.05	0.01	1.00
1919.0	0.17	0.16	-.01	1.00
2687.0	0.41	0.24	-.17	0.00
2951.0	0.90	0.27	-.63	0.00
3785.0	1.23	0.36	-.87	0.00
3864.0	1.23	0.37	-.86	0.00
4127.5	1.42	0.39	-1.03	0.00
4703.0	1.81	0.45	-1.36	0.00

GRADIENT=1.04E-04 INTERCEPT=-.035 STANDARD DEVIATION=.0116

SAMPLE NUMBER=NB3Y SURFACE TREATMENT=INHIBISOL CLEANED.

TEMPERATURE OF TEST=102°C RELATIVE HUMIDITY OF TEST=19%

EXPOSURE TIME IN HOURS.	WEIGHT GAIN IN MG/CM2.	FIT OF POINT TO LINE.	ERROR OF POINT.	WEIGHT OF POINT.
66.0	0.00	-.02	-.02	1.00
863.0	0.05	0.08	0.03	1.00
1919.0	0.21	0.22	0.01	1.00
2687.0	0.34	0.32	-.02	1.00
2951.0	0.87	0.36	-.51	0.00
3785.0	1.20	0.47	-.73	0.00
3864.0	1.20	0.48	-.72	0.00
4127.5	1.36	0.51	-.85	0.00
4703.5	1.56	0.59	-.97	0.00

GRADIENT=1.33E-04 INTERCEPT=-.034 STANDARD DEVIATION=.0253

SAMPLE NUMBER=NB12X HT SURFACE TREATMENT=ELECTROPOLISHED.

TEMPERATURE OF TEST=102°C RELATIVE HUMIDITY OF TEST=19%

EXPOSURE TIME IN HOURS.	WEIGHT GAIN IN MG/CM2.	FIT OF POINT TO LINE.	ERROR OF POINT.	WEIGHT OF POINT.
336.0	0.02	0.02	0.00	1.00
864.0	0.03	0.04	0.01	1.00
1896.0	0.09	0.08	-.01	1.00
2730.0	0.12	0.12	0.00	1.00
2807.0	0.12	0.13	0.01	0.00
3070.5	0.12	0.14	0.02	0.00

GRADIENT=4.4E-05 INTERCEPT=0 STANDARD DEVIATION=7E-03

SAMPLE NUMBER=NB12Y HT SURFACE TREATMENT=ELECTROPOLISHED.

TEMPERATURE OF TEST=102°C RELATIVE HUMIDITY OF TEST=19%

EXPOSURE TIME IN HOURS.	WEIGHT GAIN IN MG/CM2.	FIT OF POINT TO LINE.	ERROR OF POINT.	WEIGHT OF POINT.
336.0	0.02	0.04	0.02	1.00
864.0	0.03	0.05	-.02	1.00
1896.0	0.09	0.06	-.01	1.00
2730.0	0.09	0.08	0.00	1.00
2807.0	0.07	0.08	0.01	1.00
3070.5	0.08	0.08	0.00	1.00

GRADIENT=1.6E-05 INTERCEPT=-.035 STANDARD DEVIATION=.0158

TABLE 23

SAMPLE NUMBER=NB3X SURFACE TREATMENT=INHIBISOL CLEANED.

TEMPERATURE OF TEST=102°C RELATIVE HUMIDITY OF TEST=19%

EXPOSURE TIME IN HOURS.	WEIGHT GAIN IN MG/CM2.	FIT OF POINT TO LINE.	ERROR OF POINT.	WEIGHT OF POINT.
66.0	-0.02	-0.65	-0.63	0.00
863.0	0.04	-0.24	-0.28	0.00
1919.0	0.17	0.31	0.14	0.00
2687.0	0.41	0.70	0.29	0.00
2951.0	0.90	0.84	-0.06	1.00
3785.0	1.23	1.27	0.04	1.00
3864.0	1.23	1.31	0.08	1.00
4127.5	1.42	1.44	0.02	1.00
4703.0	1.81	1.74	-0.07	1.00

GRADIENT=5.14E-04 INTERCEPT=-0.68 STANDARD DEVIATION=0.0657

SAMPLE NUMBER=NB3Y SURFACE TREATMENT=INHIBISOL CLEANED.

TEMPERATURE OF TEST=102°C RELATIVE HUMIDITY OF TEST=19%

EXPOSURE TIME IN HOURS.	WEIGHT GAIN IN MG/CM2.	FIT OF POINT TO LINE.	ERROR OF POINT.	WEIGHT OF POINT.
66.0	0.00	-0.28	-0.28	0.00
863.0	0.05	0.03	-0.02	0.00
1919.0	0.21	0.45	0.24	0.00
2687.0	0.34	0.76	0.42	0.00
2951.0	0.87	0.87	0.00	1.00
3785.0	1.20	1.20	0.00	1.00
3864.0	1.20	1.23	0.03	1.00
4127.5	1.36	1.33	-0.03	1.00
4703.5	1.56	1.56	0.00	1.00

GRADIENT=0.98E-04 INTERCEPT=-0.309 STANDARD DEVIATION=0.02

TABLE 22

SAMPLE NUMBER=NB21X SURFACE TREATMENT=INHIBISOL CLEANED.

TEMPERATURE OF TEST=110°C RELATIVE HUMIDITY OF TEST=19%

EXPOSURE TIME IN HOURS.	WEIGHT GAIN IN MG/CM ² .	FIT OF POINT TO LINE.	ERROR OF POINT.	WEIGHT OF POINT.
216.5	0.05	0.03	-0.02	1.00
384.5	0.15	0.17	0.02	1.00
552.5	0.31	0.32	0.01	1.00
720.5	0.47	0.46	-0.01	1.00
1536.5	1.56	1.15	-0.41	0.00
1632.5	13.41	1.23	-12.18	0.00

GRADIENT=8.45E-04 INTERCEPT=-.151 STANDARD DEVIATION=.0201

SAMPLE NUMBER=NB21Y SURFACE TREATMENT=INHIBISOL CLEANED.

TEMPERATURE OF TEST=110°C RELATIVE HUMIDITY OF TEST=19%

EXPOSURE TIME IN HOURS.	WEIGHT GAIN IN MG/CM ² .	FIT OF POINT TO LINE.	ERROR OF POINT.	WEIGHT OF POINT.
216.5	0.04	0.06	0.02	1.00
384.5	0.30	0.29	-0.01	1.00
552.5	0.54	0.52	-0.02	1.00
720.5	0.73	0.75	0.02	1.00
1536.5	2.66	1.87	-0.79	0.00
1632.5	2.80	2.00	-0.80	0.00
1896.5	3.50	2.37	-1.13	0.00
2136.5	4.36	2.70	-1.66	0.00
2400.5	4.97	3.06	-1.91	0.00

GRADIENT=1.375E-03 INTERCEPT=-.242 STANDARD DEVIATION=.0202

SAMPLE NUMBER=K2 SURFACE TREATMENT=INHIBISOL CLEANED.

TEMPERATURE OF TEST=110°C RELATIVE HUMIDITY OF TEST=19%

EXPOSURE TIME IN HOURS.	WEIGHT GAIN IN MG/CM ² .	FIT OF POINT TO LINE.	ERROR OF POINT.	WEIGHT OF POINT.
168.0	-0.07	-0.08	-0.01	1.00
336.0	0.00	0.01	0.01	1.00
504.0	0.11	0.10	-0.01	1.00
1320.0	1.96	0.54	-1.42	0.00
1416.0	2.00	0.59	-1.41	0.00
1680.0	2.66	0.73	-1.93	0.00
1920.0	3.57	0.86	-2.71	0.00
2184.0	4.25	1.00	-3.25	0.00

GRADIENT=5.36E-04 INTERCEPT=-.167 STANDARD DEVIATION=.0109

TABLE 23

SAMPLE NUMBER=NB21Y SURFACE TREATMENT=INHIBISOL CLEANED.

TEMPERATURE OF TEST=110°C RELATIVE HUMIDITY OF TEST=19%

EXPOSURE TIME IN HOURS.	WEIGHT GAIN IN MG/CM2.	FIT OF POINT TO LINE.	ERROR OF POINT.	WEIGHT OF POINT.
216.5	0.04	-1.09	-1.13	0.00
384.5	0.30	-.62	-.92	0.00
552.5	0.54	-.15	-.69	0.00
720.5	0.73	0.31	-.42	0.00
1536.5	2.66	2.59	-.07	1.00
1632.5	2.80	2.86	0.06	1.00
1896.5	3.50	3.59	0.09	1.00
2136.5	4.36	4.26	-.10	1.00
2400.5	4.97	5.00	0.03	1.00

GRADIENT=2.786E-03 INTERCEPT=-1.693 STANDARD DEVIATION=.0837

SAMPLE NUMBER=K2 SURFACE TREATMENT=INHIBISOL CLEANED.

TEMPERATURE OF TEST=110°C RELATIVE HUMIDITY OF TEST=19%

EXPOSURE TIME IN HOURS.	WEIGHT GAIN IN MG/CM2.	FIT OF POINT TO LINE.	ERROR OF POINT.	WEIGHT OF POINT.
168.0	-.07	-1.40	-1.33	0.00
336.0	0.00	-.93	-.93	0.00
504.0	0.11	-.46	-.57	0.00
1320.0	1.96	1.82	-.14	1.00
1416.0	2.00	2.08	0.08	1.00
1680.0	2.66	2.82	0.16	1.00
1920.0	3.57	3.49	-.08	1.00
2184.0	4.25	4.23	-.02	1.00

GRADIENT=2.792E-03 INTERCEPT=-1.87 STANDARD DEVIATION=.127

TABLE 24

WEIGHT GAINS FOR URANIUM-NIOBIUM ALLOY IN MOIST AIR

Temperature (°C)	Relative Humidity (%)	Sample No.*	Initial Reaction Rate ($\mu\text{g}/\text{cm}^2/\text{h}$)	Later Reaction Rate ($\mu\text{g}/\text{cm}^2/\text{h}$)	Comments
50	75	(Nb 5XHT	0	-	Weight changes between -0.04 and $+0.04 \text{ mg}/\text{cm}^2$ in 4126 h (5 months)
		(Nb 5YHT	0	-	
		(Nb 6X	0	-	
		(Nb 6Y	0	-	
	32	(Nb 7XHT	0	-	
		(Nb 7YHT	0	-	
		(Nb 8X	0	-	
		(Nb 8Y	0	-	
		(Nb 9XHT	0	-	
	17	(Nb 9YHT	0	-	
		(Nb 9YHT	0	-	
	74	(Nb 48AXHT	0.008	-	
		(Nb 49AX	0.009	-	
	27	(Nb 50AXHT	0.006	-	
		(Nb 51AX	0.019	-	
80	19	(Nb 52AXHT	0.004	-	Test duration 11141 h. Maximum weight gain $0.26 \text{ mg}/\text{cm}^2$ in 15 months
		average: NHT	0.014	-	
		HT	0.006	-	
	74	(Nb 41X	0.029	0.094	
		(Nb 42Y	0.029	0.094	
		(Nb 43XHT	0.020	-	
	26	(Nb 44X	-	0.095	
		(			
		(			
		(			
		(Nb 45XHT	0.007	-	
	19	(Nb 46X	-	0.116	
		(			
		(			
		(			
		(Nb 47XHT	0.012	-	
91		average: NHT	0.029	0.094	Weight gain $0.58 \text{ mg}/\text{cm}^2$ in 1277 h, then weight loss. Linear weight gain from 6892 h. Jump in weight in first 1277 h, then slow final rate
		HT	0.013	-	
		(Nb 1X	0.15	1.18	
		(			
		(			
	74	(			
		(			
		(			
		(			
		(			
102	74	(			Rapid reaction at one corner of sample, then slow weight increase, then final steady weight increase
		(			
		(			
		(			
		(			
	74	(			Steady weight increase for 2687 h, then sharp increase in rate and yellow oxide (UO_3) formed.
		(			
		(			
		(			
		(			

*Sample numbers with suffix HT refer to heat-treated samples, other samples were not-heat-treated.

Letters X or Y indicate direction of cut.

TABLE 24 (continued)

<u>Temperature</u> (°C)	<u>Relative Humidity</u> (%)	<u>Sample No.</u>	<u>Initial Reaction Rate</u> ($\mu\text{g}/\text{cm}^2/\text{h}$)	<u>Later Reaction Rate</u> ($\mu\text{g}/\text{cm}^2/\text{h}$)	<u>Comments</u>
102	74	(Nb 1Y	0.14	1.34	Steady weight increase for 2687 h, then sharp increase in rate.
		(			
		(			
		(			
		(Nb 10YHT	0.063	0	Steady weight increase for 2730 h, then no change
		(			
		(			
		(			
	23	(Nb 2X	0.24	0.55	Steady weight increase for 1919 h then sharp increase in weight and yellow oxide (UO_3) formed
		(			
		(			
		(			
		(Nb 2Y	0.30	2.16	Steady weight increase for 3785 h then sharp weight increase.
		(			
		(			
		(			
		(Nb 11XHT	0.069	0	Steady weight increase for 2807 h then no increase
		(			
		(			
		(			
110		(Nb 11YHT	-	0	Sharp weight increase between 864 and 1896 h, then little change
		(			
		(			
		(			
	19	(Nb 3X	0.10	0.51	Steady weight increase for 1919 h then sharp increase in rate.
		(			
		(			
		(			
		(Nb 3Y	0.13	0.40	Steady weight increase for 2687 h then sharp increase
		(			
		(			
		(			
		(Nb 12XHT	0.044	0	Steady weight increase for 2730 h then no change
		(			
		(			
		(			
		(Nb 12YHT	0.016	0	Very little weight change.
		average: NHT	0.177	1.02	
		HT	0.048	-	
		(			
	19	(Nb 21X	0.85	-	Steady weight increase for 1536 h then sharp increase
		(			
		(			
		(Nb 21Y	1.38	2.79	Steady weight increase for 720 h, then sharp increase
		(			

TABLE 24 (continued)

<u>Temperature</u> (°C)	<u>Relative</u> <u>Humidity</u> (%)	<u>Sample No.</u>	<u>Initial</u> <u>Reaction Rate</u> (µg/cm ² /h)	<u>Later</u> <u>Reaction</u> <u>Rate</u> (µg/cm ² /h)	<u>Comments</u>
110	19	(K2	0.54	2.79	Initial 3 points do not lie on a straight line, but later 5 points fall on good straight line. Sample treated with K10.
		(			
		(			
		(			
		(			
		(			
		(average: NHT	0.92	2.79	

TABLE 25

HYDROGEN EVOLUTION MEASUREMENTS FOR NOT-HEAT-TREATED SAMPLES

<u>Sample No.</u>	<u>Direction of Cut</u>	<u>Temperature (°C)</u>	<u>Relative Humidity (%)</u>	<u>Hydrogen Evolution Rate (std cc/cm²/h/torr^{1/2})</u>	<u>Comments</u>
Nb 3	X	75	29	0	No hydrogen detected in 1920 h. High initial oxygen content (6 std cc)
Nb 4	Y	100	74	-	Large hydrogen production but not linear rate. Very high initial oxygen content (27 std cc).
Nb 5	Y	75	74	0.00027	-
Nb 6	X	100	74	0.0106	
Nb 8	X	100	19	0.0033	
Nb 9	Y	100	19	-	Hydrogen detected at only 3 samplings before cell leaked.
Nb A	X	90	74	0	No hydrogen detected in 42 h.
Nb B	X	90	74	0.0011	
Nb C	X	90	74	-	Only 2 measurements
Nb K	X	90	74	0.00061	
Nb L	X	75	74	-	Very high oxygen level, interpretation of results doubtful
Nb N	X	93	25	0.00059	
Nb R	X	75	18	0.00029	
Nb T	X	93	25	0.0011	
Nb Y	X	60	100	0	No hydrogen in 3425.5 h but high oxygen level. Pumped out and refilled to continue as Nb Y(2)
Nb Y(2)	X	60	100	0	Maximum 0.0002 std cc/cm ² . However still high oxygen level.
Nb V	X	60	75	0	Maximum 0.0018 std cc/cm ² hydrogen in 4705.5 h. Pumped out and refilled to continue as Nb V(2)
Nb V(2)	X	60	75	0	Maximum 0.0003 std cc/cm ² hydrogen in 3507 h. High oxygen level.
Nb X	X	60	15	0	No hydrogen in 2826 h. Pumped out and refilled to continue as Nb H(2).

TABLE 25 (continued)

HYDROGEN EVOLUTION MEASUREMENTS FOR NOT-HEAT-TREATED SAMPLES

<u>Sample No.</u>	<u>Direction of Cut</u>	<u>Temperature (°C)</u>	<u>Relative Humidity (%)</u>	<u>Hydrogen Evolution Rate (std cc/cm²/h/torr^{1/2})</u>	<u>Comments</u>
Nb H(2)	X	60	15	0	Maximum 0.0001 std cc/ cm ² hydrogen in 3484.5 h. High oxygen level.

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TABLE 26

HYDROGEN EVOLUTION MEASUREMENTS FOR NOT-HEAT-TREATED
SAMPLES TREATED WITH K10

<u>Sample No.</u>	<u>Direction of Cut</u>	<u>Temperature (°C)</u>	<u>Relative Humidity (%)</u>	<u>Hydrogen Evolution Rate (std cc/cm²/h/torr^{1/2})</u>	<u>Comments</u>
K 1	Y	100	74	0.0023	Only 3 points. Test 47 h only.
K 2	Y	75	74	0	No hydrogen detected in 598 h. Air leaked after 356 h.
K 3	X	100	19	0	< 0.004 std cc H ₂ /cm ² in 576 h.
K 4	Y	100	19	0	< 0.004 std cc H ₂ /cm ² in 576 h.
K 5	X	100	74	-	0.046 std cc/cm ² in 23½ h. Only 2 measurements.
K 6	Y	100	74	0	< 0.003 std cc H ₂ /cm ² H ₂ not detected at every analysis. Slight air leak after 139 h. More air leaked after 237 h.
K H	X	93	25	0.0018	-
K F	X	70	74	0.00050	-
K G	Y	70	29	-	Maximum 0.003 std cc/cm ² hydrogen in 2056.5 h. High oxygen level.

TABLE 27

HYDROGEN EVOLUTION MEASUREMENTS FOR HEAT-TREATED SAMPLES

<u>Sample No.</u>	<u>Direction of Cut</u>	<u>Temperature (°C)</u>	<u>Relative Humidity (% RH)</u>	<u>Comments</u>
Nb 7	X	100	74	0.07 std cc H ₂ /cm ² at 93½ h. 0.47 std cc H ₂ /cm ² at 136½ h.
Nb 11	X	100	74	< 0.01 std cc H ₂ /cm ² produced in 503 h. Hydrogen detected (traces) at 3 samplings only.
Nb 12	X	75	74	< 0.005 std cc H ₂ /cm ² in 834 h. 0.015 std cc H ₂ /cm ² at 1002 h.
Nb 14	Y	100	19	No hydrogen detected in 454 h.
Nb G	Y	90	74	< 0.001 std cc H ₂ /cm ² in 68 h.
Nb M	X	93	25	0.007 std cc H ₂ /cm ² in 234 h.
Nb O	X	75	29	< 0.0013 std cc H ₂ /cm ² in 648 h.
Nb Q	X	75	18	< 0.0016 std cc H ₂ /cm ² in 263 h.
Nb S	X	93	25	< 0.005 std cc H ₂ /cm ² in 1842 h.
Nb U	X	60	75	< 0.003 std cc H ₂ /cm ² in 4557 h. Pumped out and refilled to continue as Nb U(2)
Nb U(2)	X	60	75	< 0.007 std cm/cm ² in 3100 h.
Nb W	X	60	17	No hydrogen in 3982 h. Quite high oxygen. Pumped out and refilled to continue as Nb W(2)
Nb W(2)	X	60	17	< 0.0001 std cc/cm ² in 3103 h.

TABLE 28

HYDROGEN EVOLUTION MEASUREMENTS FOR HEAT-TREATED SAMPLES TREATED WITH K10

<u>Sample No.</u>	<u>Direction of Cut</u>	<u>Temperature (°C)</u>	<u>Relative Humidity (% RH)</u>	<u>Comments</u>
KA	Y	90	74	0.0005 std cc/cm ² in 18 h. Only one measurement.
KB	Y	75	74	No hydrogen detected in 18 h.
KC	X	70	74	No hydrogen detected in 1884 h.
KD	X	70	29	< 0.03 std cc H ₂ /cm ² in 2158.5 h. Quite high oxygen.
KE	X	90	26	< 0.001 std cc H ₂ /cm ² in 2496 h. Quite high oxygen.
KI	X	70	18	No hydrogen detected in 928 h.
KL	X	60	30	< 0.002 std cc H ₂ /cm ² in 1665.5 h. Quite high oxygen. Pumped out and refilled to continue as KL(2).
KL (2)	X	60	30	< 0.002 std cc H ₂ /cm ² in 3027 h.

TABLE 29HYDROGEN EVOLUTION MEASUREMENTS FOR WR SAMPLES

<u>Sample No.</u>	<u>Temperature (°C)</u>	<u>Relative Humidity (% RH)</u>	<u>Comments</u>
C1	90	74	< 0.003 std cc H ₂ /cm ² in 3548 h.
C2	75	74	< 0.002 std cc H ₂ /cm ² in 3548 h.
C3	90	19	< 0.005 std cc H ₂ /cm ² in 3403 h.
C4	90	19	< 0.0022 std cc H ₂ /cm ² in 3403 h.
C5	75	19	< 0.0013 std cc H ₂ /cm ² in 3216 h.
C6	75	19	< 0.019 std cc H ₂ /cm ² in 3121 h.

No K10 on these samples

TABLE 30
URANIUM-NIOBIUM ALLOY/WATER VAPOUR REACTION - MICROBALANCE RESULTS OF
NOT-HEAT-TREATED SAMPLES

Temperature (°C)	Dew Point (°C)	Water Vapour Pressure, p (torr)	Rate of Weight Gain ($\mu\text{g}/\text{cm}^2/\text{h}$)	Rate $\div p^{\frac{1}{2}}$ ($\mu\text{g}/\text{cm}^2/\text{h}/\text{torr}^{\frac{1}{2}}$)
90	60.4	152.1	8.8	0.71
100	60.4	152.1	13.0	1.05
110	60.4	152.1	22.5	1.82
130	60.4	152.1	56.7	4.60
130	60.4	152.1	48	3.89
150	60.4	152.1	122	9.89
150	60.4	152.1	95	7.70
110	50.0	92.5	16.2	1.69
110	40.0	55.3	12.0	1.62

TABLE 31
URANIUM-NIOBIUM ALLOY/WATER VAPOUR REACTION -
RESULTS OF GAS PRESSURE MEASUREMENTS

Type of Sample	Temperature (°C)	Dew Point (°C)	Water Vapour Pressure, p (torr)	Rate of Hydrogen Evolution (std cc/cm ² /h)	Equivalent Weight Gain ($\mu\text{g}/\text{cm}^2/\text{h}$)	Rate $\div p^{\frac{1}{2}}$ ($\mu\text{g}/\text{cm}^2/\text{h}/\text{torr}^{\frac{1}{2}}$)
NHT	145	20.1	17.6	0.081	58	13.8
NHT	142	19.3	16.8	0.074	53	12.9
HT	250	20.1	17.6	0.0011	0.75	0.18

TABLE 32
COMPARISON OF RATES OF REACTION OF URANIUM AND URANIUM-6% NIOBIUM
ALLOY (NOT-HEAT-TREATED) WITH WATER VAPOUR

Temperature (°C)	Water Vapour Pressure (torr)	k_{UNb}^* ($\mu\text{g wt gain}/\text{cm}^2/\text{h}$)	k_{U}^+ ($\mu\text{g wt gain}/\text{cm}^2/\text{h}$)	$k_{\text{UNb}}/k_{\text{U}}$
20	4	0.14	0.68	0.20
50	4	0.61	2.86	0.21
100	4	4.46	18.7	0.24
20	16	0.27	1.36	0.20
50	16	1.23	5.72	0.22
100	16	8.93	37.4	0.24

* from equation (2)

+ from equation (4)

TABLE 33
AVRAMI FIT TO WEIGHT GAIN MEASUREMENTS

<u>Sample No.</u>	<u>Temperature (°C)</u>	<u>Relative Humidity (%)</u>	<u>k ($\mu\text{g}/\text{cm}^2/\text{h}$)</u>	<u>α (h^{-1})</u>	<u>$\frac{1}{2}k\alpha$ ($\mu\text{g}/\text{cm}^2/\text{h}^2$)</u>	<u>Comments</u>
Ib41X	91	74	1.28×10^{-4}	1.40×10^{-4}	8.96×10^{-9}	)Points at 9928 and 11001 h omitted)from the fit as they do not lie on)the smooth curve joining the other)points.
Ib42Y	91	74	1.61×10^{-4}	9.22×10^{-4}	7.42×10^{-9}	
Ib44X	91	26	9.32×10^{-5}	4.10×10^{-4}	1.91×10^{-8}	Points up to 2687 h only used as later points do not lie on smooth curve.
Ib1X	102	74	2.11×10^{-4}	1.25×10^{-3}	1.32×10^{-7}	
Ib1Y	102	74	1.77×10^{-4}	1.50×10^{-3}	1.33×10^{-7}	Points up to 1919 h only used as later points do not lie on smooth curve.
Ib2X	102	23	7.12×10^{-4}	6.42×10^{-4}	2.29×10^{-7}	)
Ib2Y	102	23	4.43×10^{-4}	1.02×10^{-3}	2.26×10^{-7}	
Ib3X	102	19	1.71×10^{-2}	6.4×10^{-6}	5.49×10^{-8}	)Points up to 2687 h only used as later)points do not line on smooth curve.)
Ib3Y	102	19	1.98×10^{-4}	9.58×10^{-4}	9.49×10^{-8}	
Ib1X, 1Y, 3X and 3Y together)	102	19 and 74	2.37×10^{-4}	8.10×10^{-4}	9.57×10^{-8}	)
Ib2X and 2Y together)	102	23	4.38×10^{-4}	1.05×10^{-3}	2.30×10^{-7}	
Ib21X	110	19	1.62×10^{-3}	1.60×10^{-3}	1.29×10^{-6}	Point at 1536.5 h for Nb21X omitted as it does not lie on a smooth curve with the other points
Ib21Y	110	19	3.01×10^{-3}	1.29×10^{-3}	1.94×10^{-6}	
K2	110	19	4.70×10^{-3}	5.53×10^{-4}	1.30×10^{-6}	
Ib21X, 21Y and K2 together)	110	19	3.88×10^{-3}	7.62×10^{-4}	1.48×10^{-6}	

TABLE 34

COMPARISON OF RATES OF REACTION OF URANIUM AND URANIUM-6% NIOBIUM ALLOY
WITH OXYGEN AND WATER VAPOUR

Temperature (°C)	Initial Rate (U-Nb)* (μg wt gain/cm ² /h)		Final Rate (U-Nb)* (μg wt gain/cm ² /h)		Rate (U)† (μg wt gain/cm ² /h)
	NHT	HT	NHT	HT	
80 (range: (average:	0.009-0.019 0.014	0.004-0.008 0.006	***	***	3.2
91 (range: (average:	0.029†† 0.029	0.007-0.020 0.013	0.094-0.095	***	9.8
102 (range (average:	0.14-0.30 0.177	0.016-0.069 0.048	0.4-2.2 1.02	0	28
110 (range: (average:	0.5-1.4 0.92	- -	2.8††† 2.8	- -	59

* from Table 24. HT = heat-treated, NHT = not-heat-treated.

† from equation (4).

** final reaction rate not reached.

†† 2 measurements (samples Nb41X and Nb42Y)

††† 2 measurements (samples Nb21Y and K2)

TABLE 35

RATIO OF URANIUM-6% NIOBIUM ALLOY/OXYGEN/WATER REACTION RATE
TO UNALLOYED URANIUM REACTION RATE

Temperature (°C)	Initial Relative Rate (k_{UNb}/k_U)		Final Relative Rate (k_{UNb}/k_U)	
	NHT	HT	NHT	HT
80 (range: (average:	0.003-0.006 0.004	0.001-0.0025 0.002	- -	- -
91 (range: (average:	0.003 0.003	0.0007-0.002 0.001	0.01	-
102 (range: (average:	0.005-0.01 0.006	0.0006-0.002 0.002	0.01-0.08 0.04	0 0
110 (range: (average:	0.008-0.02 0.016	- -	0.05 0.05	- -

FIGURE 1 - GAS SAMPLING CELL ($\frac{1}{2}$ SCALE)

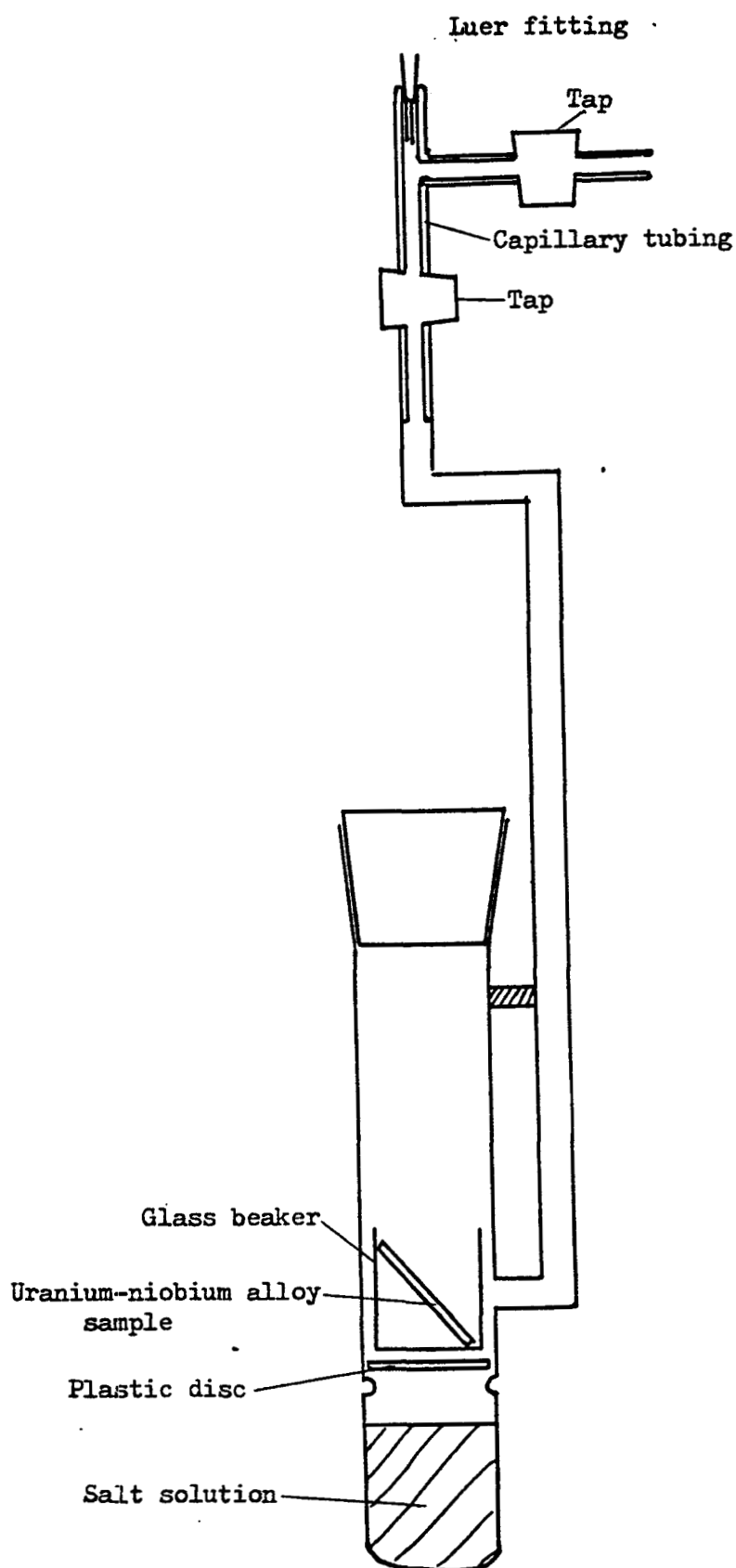


FIGURE 2 - MICROBALANCE SYSTEM (SCHEMATIC, NOT TO SCALE)

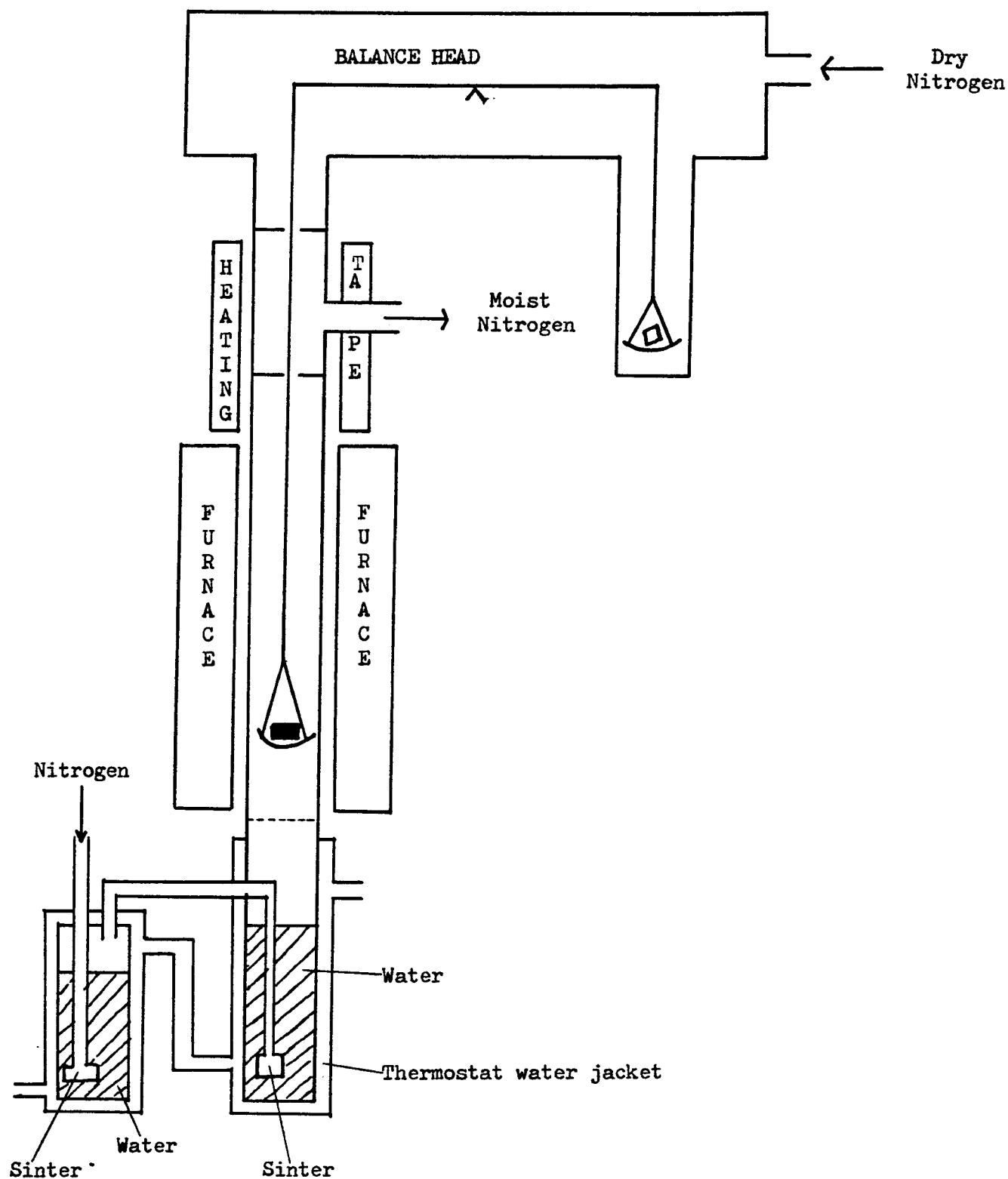
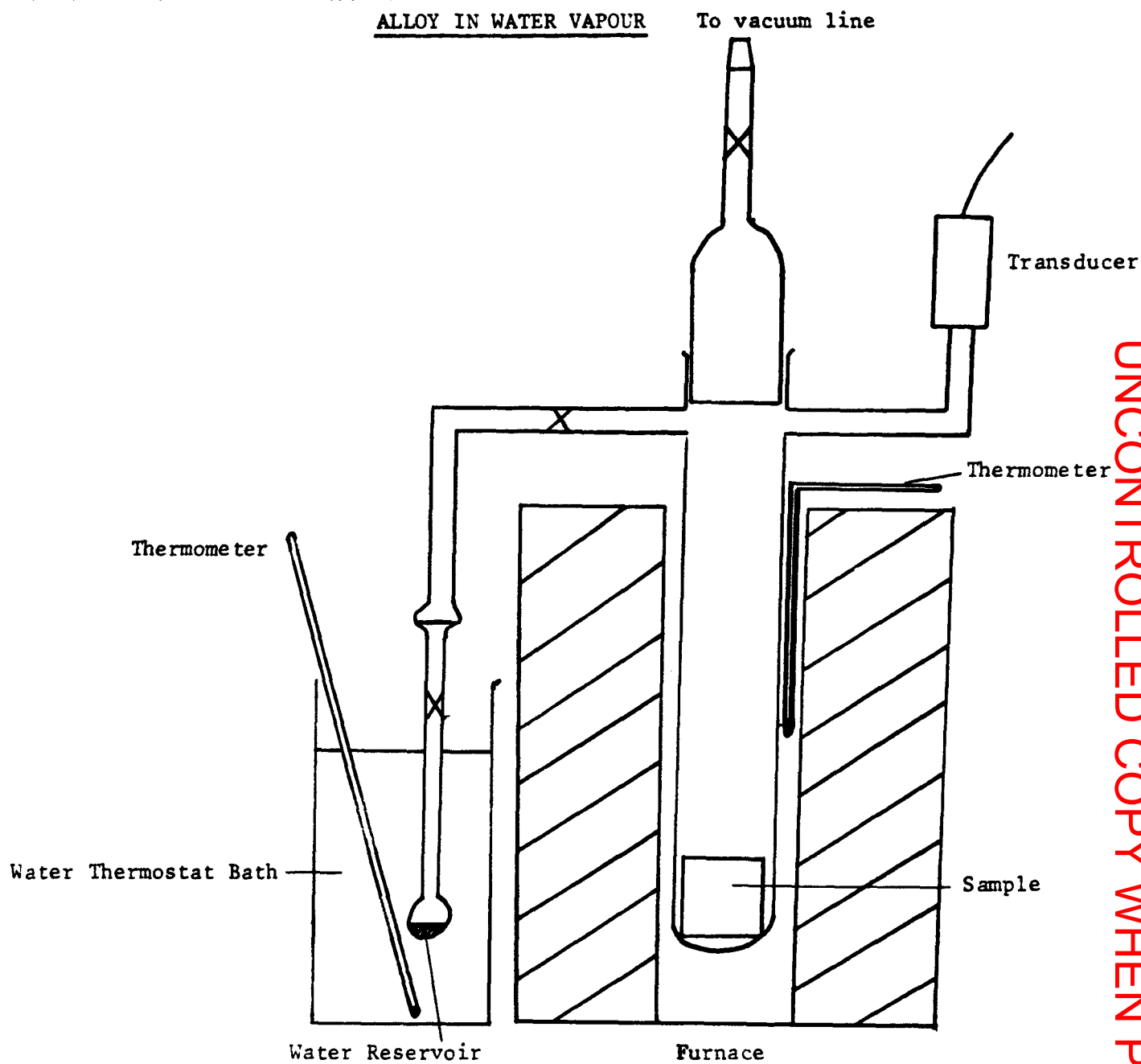


FIGURE 3

APPARATUS FOR HYDROGEN PRESSURE MEASUREMENTS FOR CORROSION OF URANIUM-NIOBIUM



X = Rotaflow Taps

FIGURE 4 - URANIUM-NIOBIUM ALLOY/OXYGEN/WATER VAPOUR REACTION AT 80°C

Δ = Nb 49 Ax
 $\square$ = Nb 51 Ax
 $\circ$ = Nb 52 Ax HT
 $\bullet$ = Nb 42 Ax HT
 $\times$ = Nb 50 Ax HT

Weight Gain
(mg/cm²)

0.6

0.5

0.4

0.3

0.2

0.1

0

2000

4000

6000

8000

10000

12000

14000

TIME (h) 51

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FIGURE 5 - URANIUM-NIOBIUM ALLOY/OXYGEN/WATER VAPOUR REACTION AT 91°C

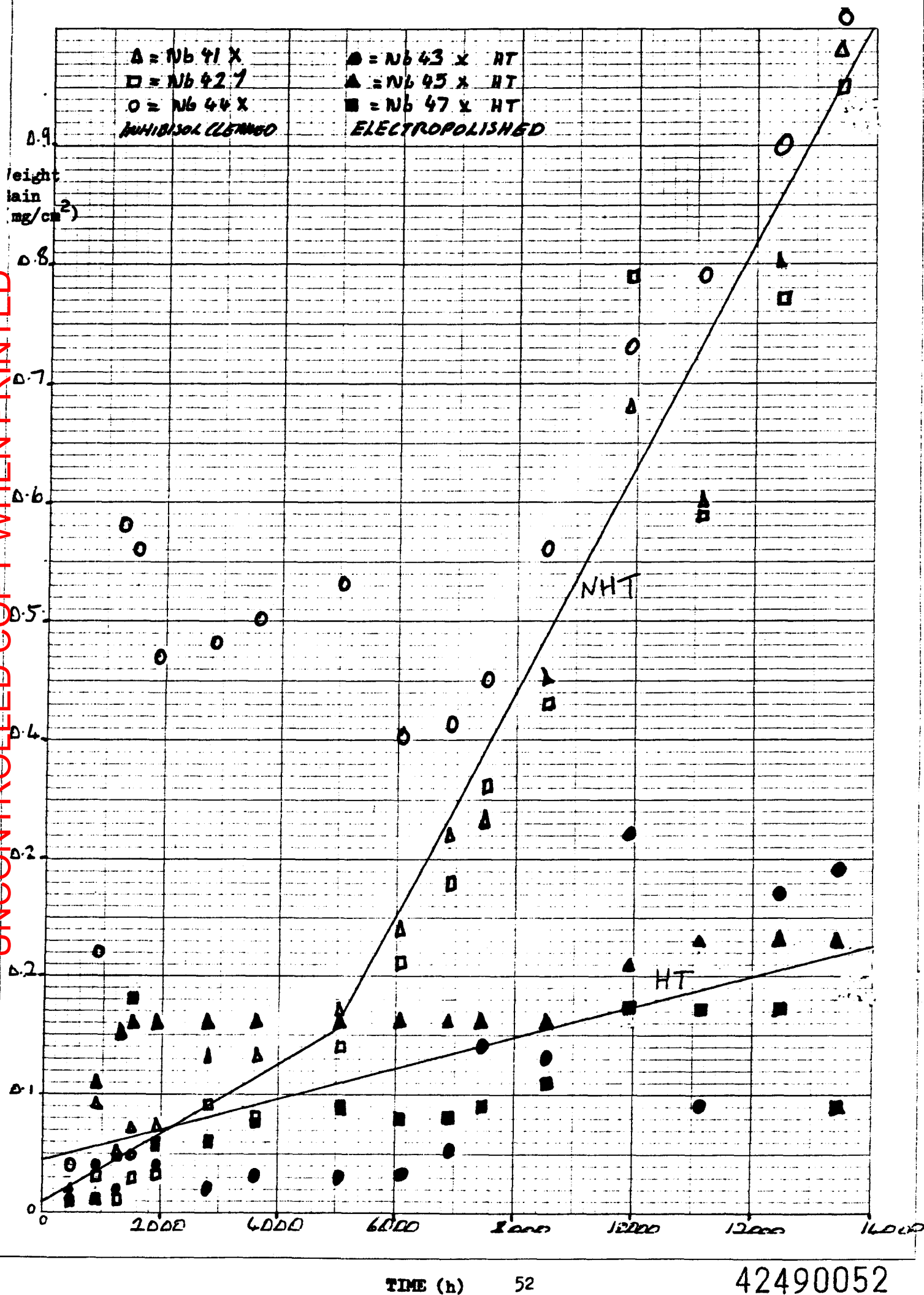


FIGURE 6 - URANIUM-NIOBIUM ALLOY/OXYGEN/WATER VAPOUR REACTION AT 102°C

NHT: ○ Nb1X □ Nb1Y ▲ Nb2X ▼ Nb2Y ◇ Nb3X × Nb3Y
HT: • Nb10HT ■ Nb11XHT ▲ Nb11YHT ▼ Nb12XHT ◆ Nb12YHT

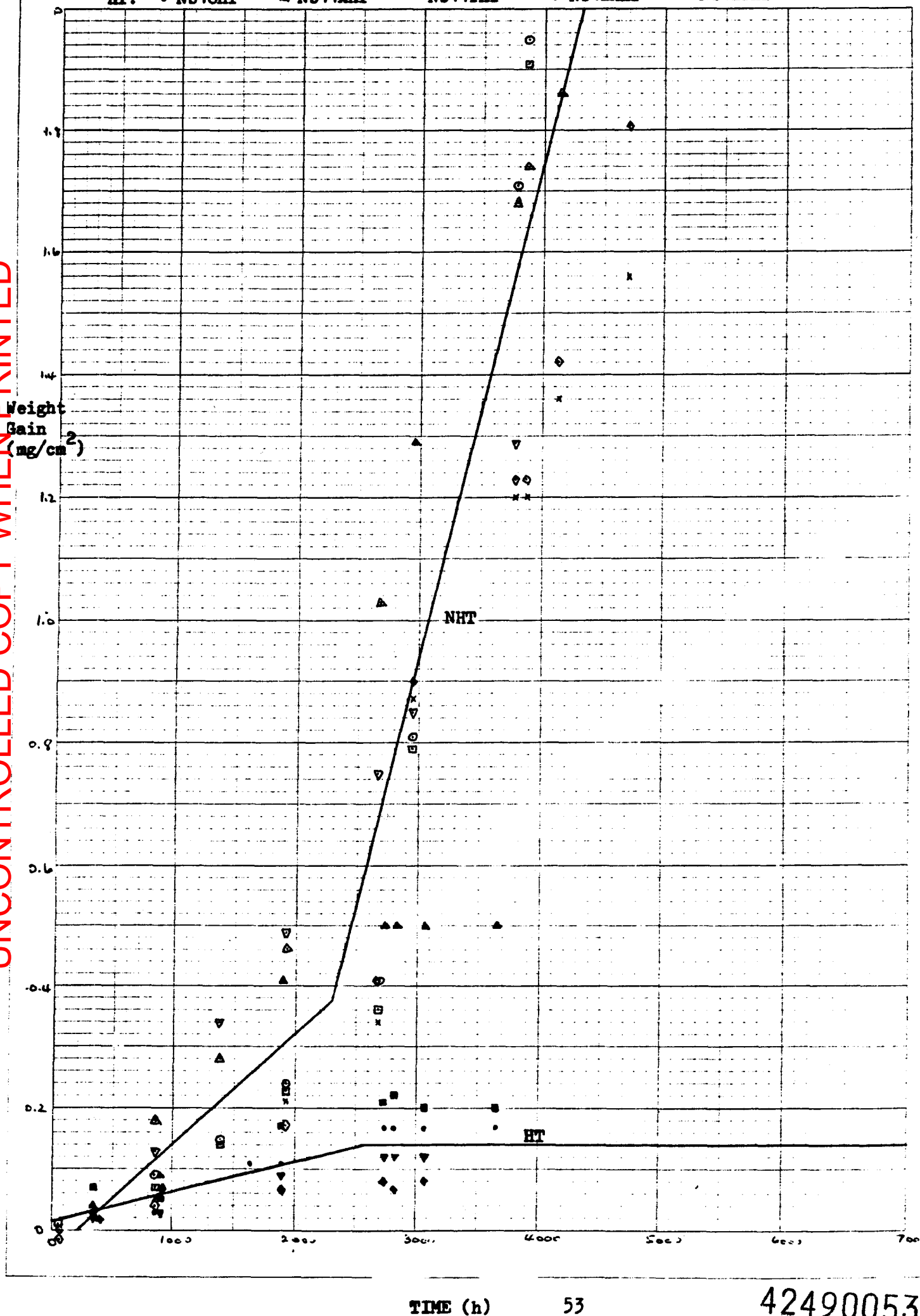
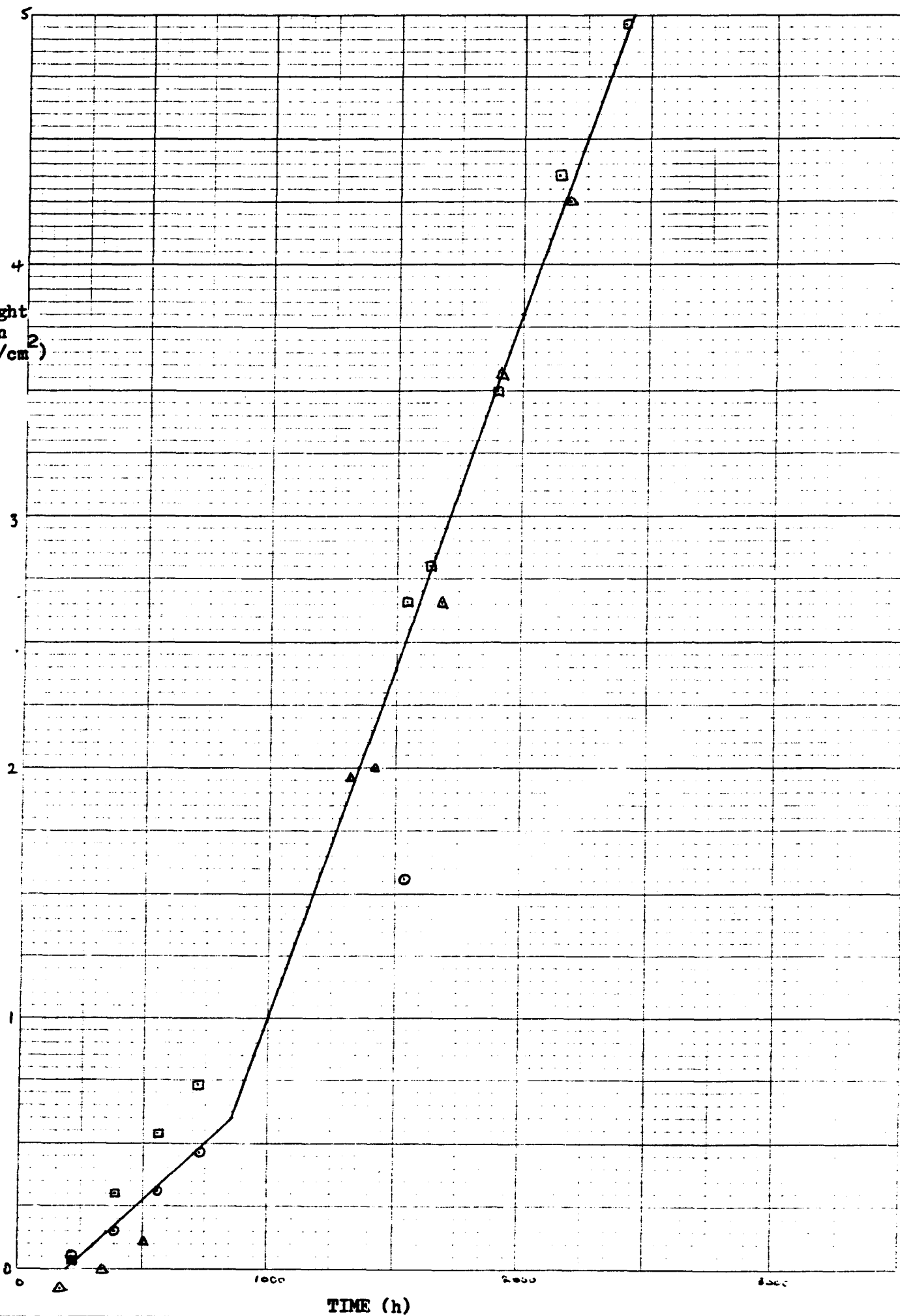


FIGURE 7 - URANIUM-NIOBIUM ALLOY/OXYGEN/WATER VAPOUR REACTION AT 110°C

NHT: ○ NbX21

□ NbY21

△ K2



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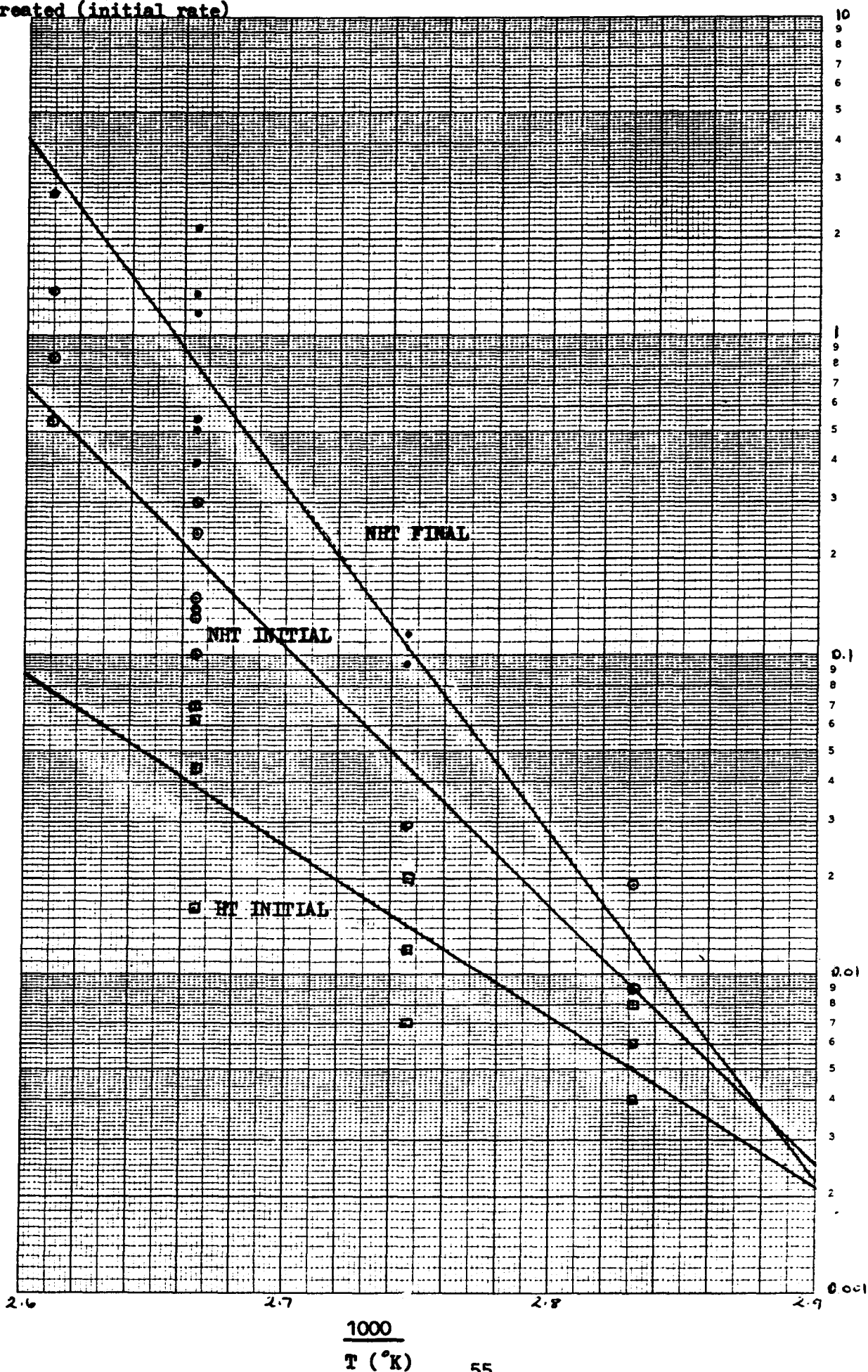
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FIGURE 8 - RATE OF REACTION OF URANIUM - 60% NIOBIUM ALLOY WITH MOIST AIR

○ Not Heat Treated (initial rate)
 ● Heat Treated (initial rate)

● Not Heat Treated (final rate)

Weight Gain
 ($\mu\text{g}/\text{cm}^2/\text{h}$)



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FIGURE 9 - HYDROGEN EVOLUTION FROM URANIUM-NIOBIUM ALLOY/WATER VAPOUR REACTION (75-93°C)

70°C: ■ KF (corrected for water vapour pressure dependence)

75°C: ○ Nb5

□ NbR

90°C: △ NbB

▽ NbK x NbC

93°C: ◇ NbN ⊗ NbT

Hydrogen
Evolved
std cc/1
(cm²/torr²)

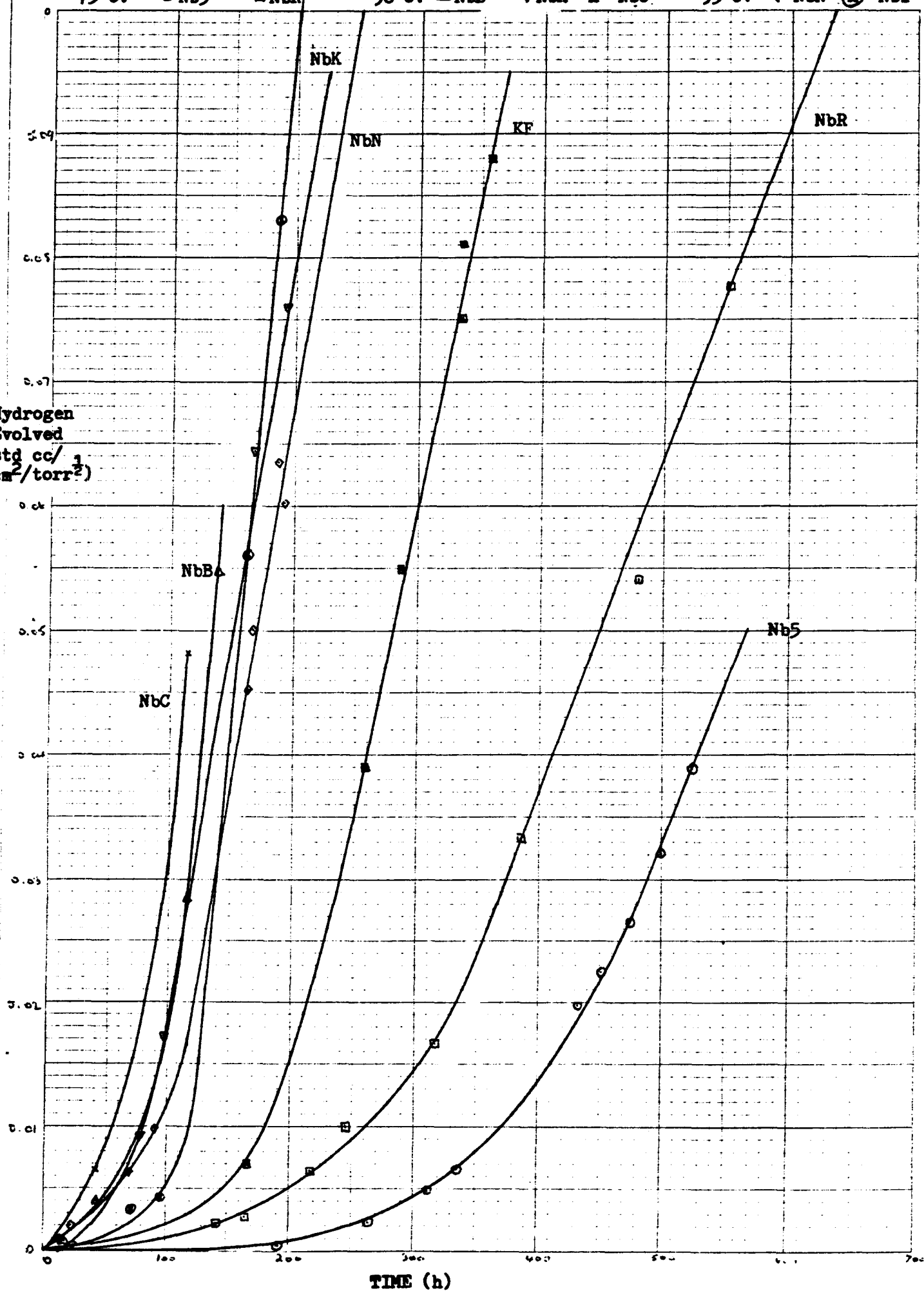
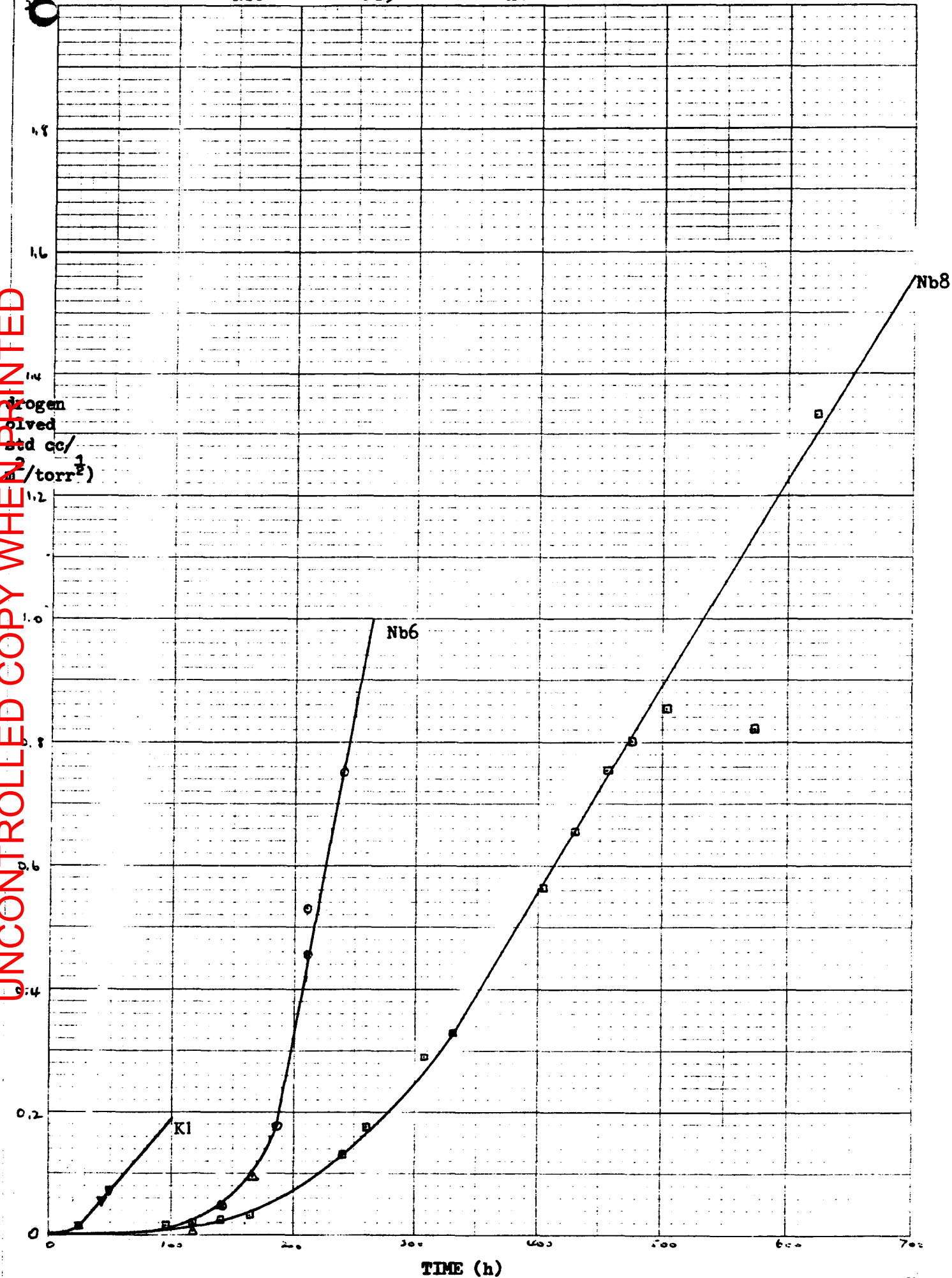


FIGURE 10 - HYDROGEN EVOLUTION FROM URANIUM-NIOBIUM ALLOY/WATER VAPOUR REACTION (100°C)
(corrected for water vapour pressure dependence)

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○ Nb6 □ Nb8 △ Nb9 ▽ K1



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FIGURE 11 - PART OF MICROBALANCE TRACE (Run 90, Not-Heat-Treated Sample,
150°C, 152 torr water vapour, 4 cm/h, full scale 1 mg)

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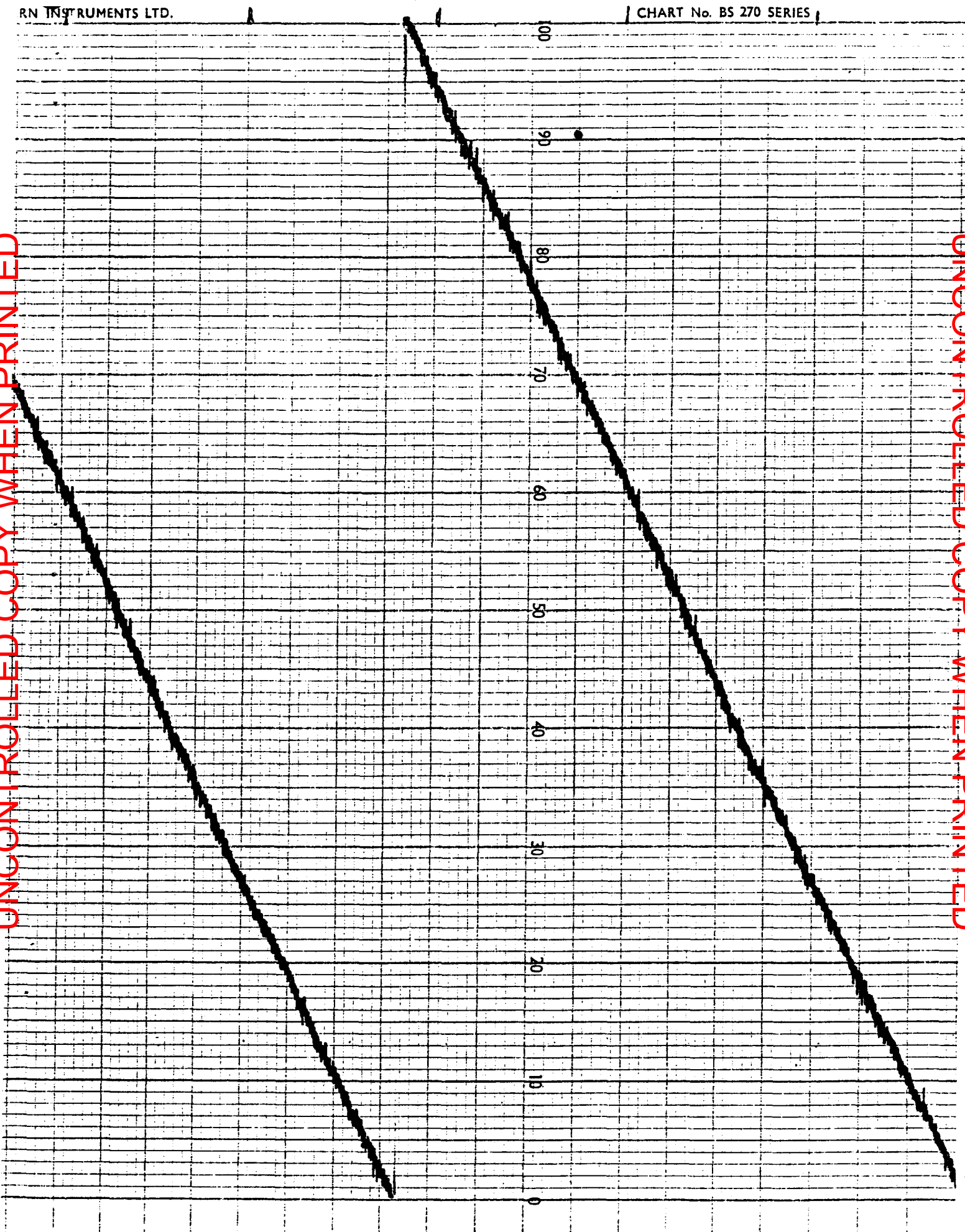
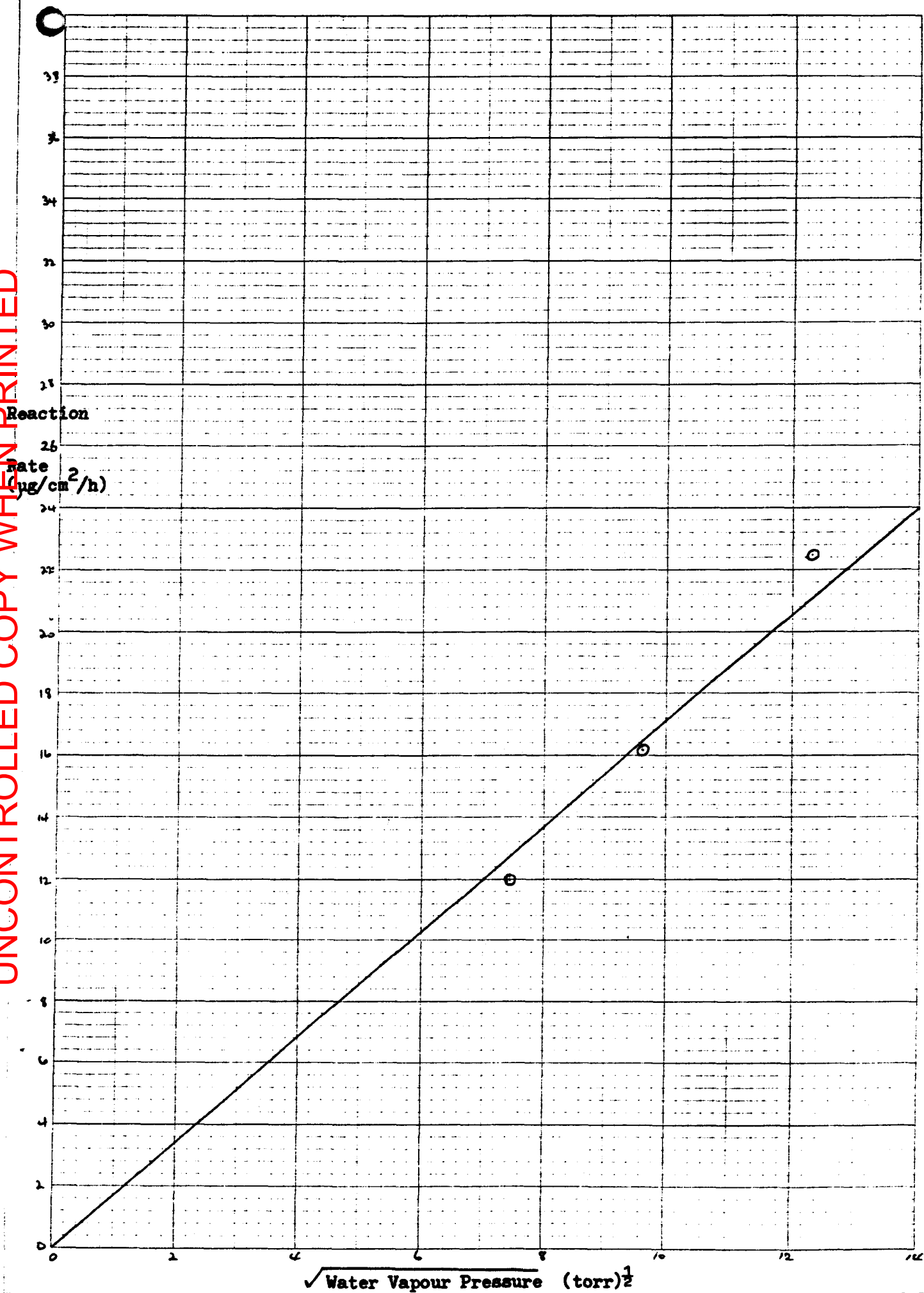


FIGURE 12 - HUMIDITY DEPENDENCE OF CORROSION RATE OF NOT-HEAT-TREATED URANIUM-NIOBIUM ALLOY AT 110°C IN MOIST NITROGEN



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FIGURE 13 - FINAL LINEAR RATE OF URANIUM-NIOBIUM ALLOY/WATER VAPOUR REACTION FOR NOT-HEAT-TREATED SAMPLES

○ Microbalance

□ Gas Analysis

△ Gas Pressure Measurement

Rate
Constant
(corrected for
water vapour
pressure
dependence)
($\mu\text{g}/\text{cm}^2/\text{h}$
/ torr^2)

Log 3 Cycles x mm, 5 and 1 c

Chartwell Graph Data Ref. 5531

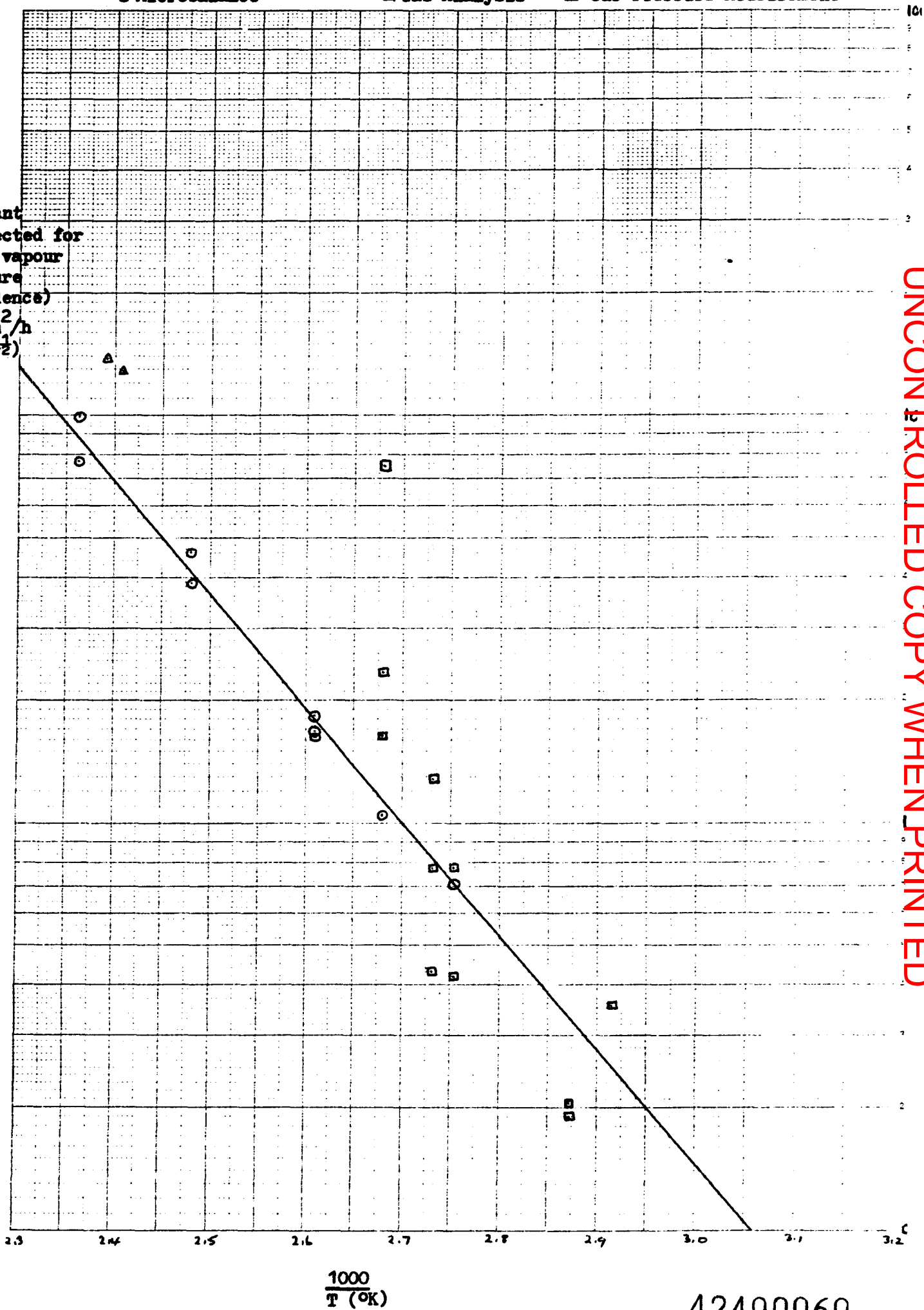
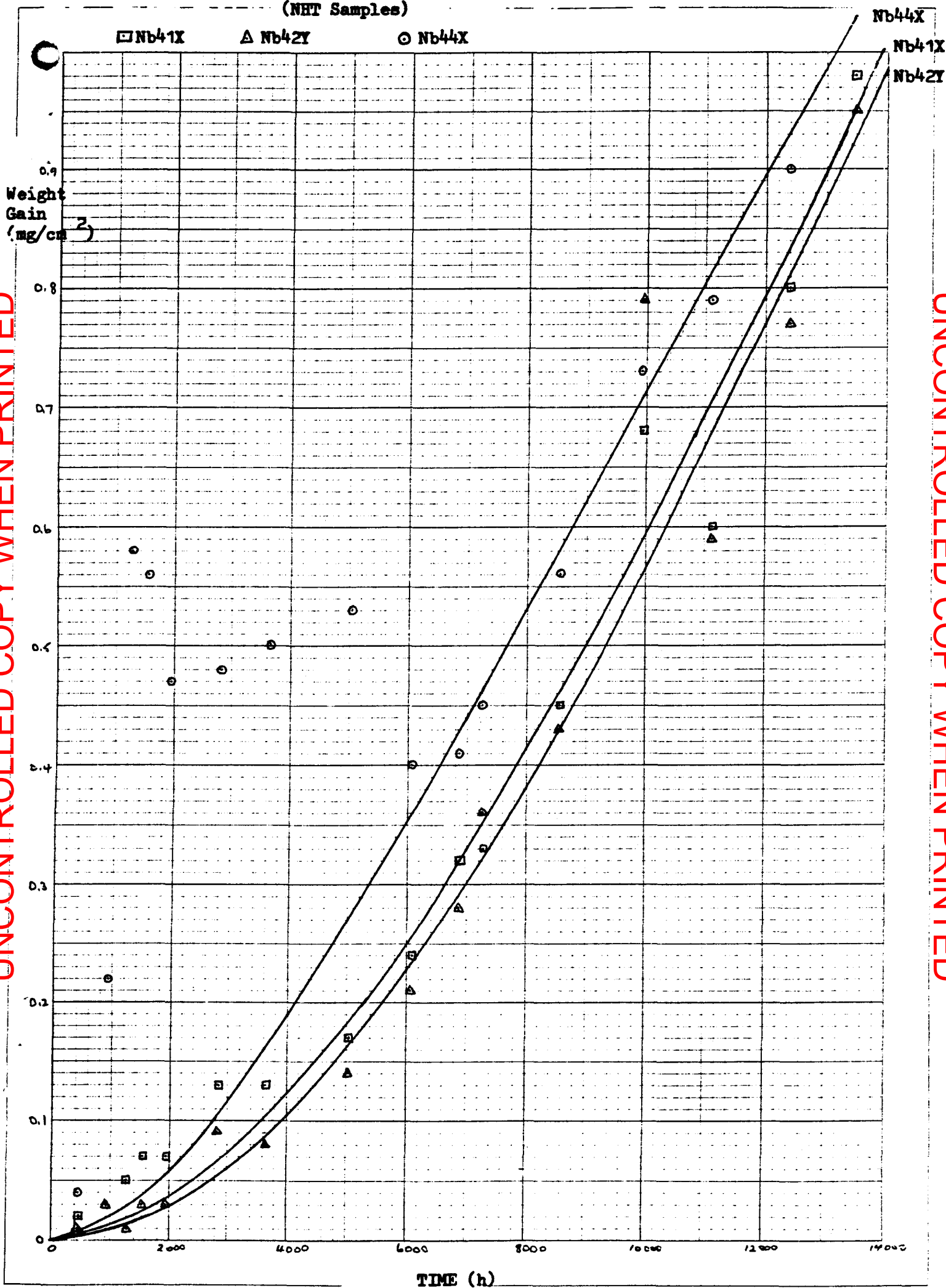


FIGURE 14 - AVRAMI FIT FOR URANIUM-NIOBIUM ALLOY/OXYGEN/WATER VAPOUR REACTION AT 91°C
(NHT Samples)



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FIGURE 15 - AVRAMI FIT FOR URANIUM-NIOBIUM ALLOY/OXYGEN/WATER VAPOUR REACTION AT 102 & 110°C (NHT Samples)

