Incident Warning Systems: Analysis of Traffic Behaviour from loop-detector data

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R-95-72

HOPES

Horizontal Project for the Evaluation of Safety

DRIVE II Project V2002
Internal report
Work package 31
Activity 31.3/ 31.4

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Deliverable type: P
Submission date: February 1995

Commission of the European Communities - R&D programme Telematics Systems in the Area of Transport (DRIVE II)

Printed at SWOV Institute for Road Safety Research,
P.o. box 1090, 2260 AD Leidschendam, The Netherlands

The research reported herein was conducted under the European Community DRIVE Programme. The project is being carried out by a consortium comprising: Institute for Transport Studies, University of Leeds; Department of Traffic Planning and Engineering, University of Lund; Swedish National Road Administration; Fachgebiet Verkehrsplanung und Verkehrswesen, Technische Universität München; Traffic Research Centre, University of Groningen; Transport Research Laboratory; Centro SStudi Sui Sistemi Transporto; FACTUM; Department of Transport and Logistics, Chalmers University of Technology; Department of Civil and Environmental Engineering, University College Cork, Technical Research Centre of Finland; Institute for Road Safety Research SWOV; Institute for Traffic Safety, TÜV Rheinland; INRETS BRON; INRETS DERA; and Swedish Road and Traffic Research Institute. The opinions, findings and conclusions expressed in this report are those of the authors alone and do not necessarily reflect those of the EC or of any organization involved in the project.

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1. INTRODUCTION

Part of the DRIVE II project HOPES is a traffic safety evaluation study regarding Incident Warning Systems (IWS). The major aim of the study is to evaluate the safety effects of different IWS-applications and to compare the outcomes. A secondary aim was to demonstrate how a full scale safety evaluation of a telematics system could be carried out, using all safety relevant events in traffic, ranging from accidents to conflicts, behavioural disturbances and undisturbed passages. The design of the total IWS-evaluation study is described in [3]. This study regards a retrospective safety evaluation. A Framework for this type of study is given in [6] en [7]. It does not regard prospective safety aspects as should have been checked at the system development stage. A framework for that type of evaluation is given in [1]. A general background for retrospective safety evaluation regarding the specific questions to deal with, is given in [2].

Three systems were selected from DRIVE II projects:
- the PORTICO system, to be implemented at the A1 motorway near Lisbon and at the IP5, a mountain road also in Portugal;
- the EURO-TRIANGLE system, to be implemented at the Antwerp motorway ring road;
- the MELYSSA system, at the A6 motorway near Lyon.

Although these systems are considerably different in local circumstances as well as in the concept of the system, they are all aiming at an improvement of safety by warning the drivers for incidents. It is assumed that the warned drivers will adept their behaviour sufficiently, to decrease the amount of potential risk.

An accident review has been carried out for the three IWS-projects and is reported in [8]. This report gives an overview of the various types of accidents at the three motorway locations and the maximum potential for an accident reduction by the system, based on the types of accidents. The effectiveness of such a warning system can finally only be proved, by showing that the number of accidents is less with the system on, and not higher with the system off. Such an evaluation is difficult to carry out at small scale implementations. Accident records should be collected over a number of years to prove statistically significant effects. Circumstances will change as well over the years, making it difficult to interpret changes in accident numbers. Furthermore, accident data does not tell how an expected effect is achieved or why it is not achieved. A careful analysis of the traffic process with and without the system installed, will give more information about the strong and weak points of such systems. A major question then is, whether road users do change their behaviour, in order to reduce risk, and how, where, when and under what conditions they change it. Such a study regards traffic speed and flow, as well as conflicts and other disturbances in the traffic process. A classical speed and flow study is covered in [4]. The analysis of traffic behaviour by human observers, on the basis of video recordings, is reported in [5]. A conflict study is carried out and reported in [9].

This report regards a computer analysis of traffic behaviour on the basis of loop-detector data. The report describes the analysis of traffic behaviour in disturbed traffic situations, including manoeuvres of road-users with various degrees of risk. A recently developed technique, based on traffic flow characteristics, has been used for the analysis. The study was part of the behavioural evaluation and based on car by car data, including traffic flows per lane, speeds, headways and interactions between cars from different lanes.
In general, traffic flow research is not focusing on the causes of incidents. It describes flows in terms of general stream characteristics (average speed or headway, speed distribution etc.).

Till now, the characteristics of traffic streams are hardly ever studied in detail to describe the aspects of risk. Incident detection systems as developed, e.g. within the DRIVE programme, concentrate on situations that already ran out of hand. Such systems detect accidents that took place or traffic streams that came to a stop. These situations are rather easy to detect, because they

can be identified directly. This is not the case with *potential danger.*
In general, traffic flow research is not focused on incidents. It describes flows in terms of general stream characteristics (average speed or headway, speed distributions etc.).
One of the fundamental characteristics of traffic flows that does not get attention in classic traffic flow theory, is the interaction between individual road users in the same lane and in other lanes.
Conflict techniques on the other hand detect interactions between road users with imminent danger in their traffic context, but these techniques isolate the events, and do not relate them to the characteristics of the traffic stream.

Incident Warning Systems aim at warning road users for special events, in order to let them adapt their behaviour to reduce the potential danger. There is general agreement about the types of events the driver should be warned for if they happen. Another ambition of some warning systems is to prevent traffic from getting into a state with an increased probability of such an event to occur. Apart from events that are not caused by human drivers themselves, such as black ice, or a punched tyre, many incidents result directly from the behaviour of road-users. This behaviour is often triggered by the traffic process itself, e.g. in case of congested lanes or lanes that are blocked. In unstable traffic situations many accidents are evoked by the characteristics of the traffic flows. Manoeuvres of other road-users, such as overtaking, braking or reacting with an evasive action, become less predictable in such situations, especially if the number of road users involved increases. If such situations can be anticipated on the basis of traffic stream characteristics, then this information can be used to improve IWS- programmes.

2. BEHAVIOURAL ANALYSIS FROM LOOP-DETECTOR DATA

2.1 Aim of the study

The major aim of the study is to define and use behavioural indicators that measure changes in the behaviour of road users as well as the risk of an accident with regard to the functioning of a incident detection and warning system.
A second aim of this study is to bridge the gap between traffic flow theory and risk detection, in order to predict the likelihood of incidents to occur, and to indicate possible improvements of (pre-) incident detection systems and incident warning messages. For both aims behaviour is defined in terms of (interactive) traffic flow characteristics.
To do this, one should first find out what characteristics of the traffic flows are potentially dangerous. One argument against this approach is, that danger is the result of human error and cannot be measured from the traffic characteristics. This position, however, is hardly tenable. Although the human error may be in the end the final cause for a particular accident, the characteristics of the traffic flows are the major conditions for human errors to be evoked. Especially, in traffic flows that become more and more unstable, the probability of incidents and accidents will increase rapidly.

A first step to be made, is trying to understand which traffic conditions are potentially dangerous. Although this knowledge is essential for guiding traffic streams, such studies are hardly ever carried out, because of their complex nature. Furthermore, these studies are traditionally made by human observers, which makes the research expensive. New techniques are available to develop (semi-) automated recording systems for this purpose.

2.2 Working procedure

A traffic safety evaluation has been carried out at the two systems in Portugal at the A1 motorway near Lisbon and the one in Belgium, at the motorway ring road in Antwerp.
The study was designed as a before-after study. The major aim was to put the safety evaluation of the warning systems in a wider perspective. This means that the study regards all aspects of the so-called safety pyramid. With this concept it is assumed that accidents show only the top of the ice-berg, and that a complete study should also take near-accidents, conflicting behaviour or other forms of risky behaviour into account, against the background of normal traffic behaviour. A complete description of the design of the study is found in the HOPES deliverable 15, "Design of Incident Warning Systems Evaluation Studies". Different aspects of the behavioural analysis are covered in "Traffic Management Evaluation", Work Package 31 of HOPES, including the study of speeds and traffic flows, traffic conflicts and traffic behaviour.

The aim of this study is:
- to develop and apply a method that is well defined, easily used and with minimal human judgement;
- to carry this study out as part of an evaluation study concerning an existing incident warning system;
- to do this for relevant and frequently occurring, but not too complicated situations.

The following procedure will be used:
- video and loop detector data will be used as a basis;
- trained human observers will select, categorize and score traffic events with a certain degree of potential risk;
- indicators will be defined, using the interactive traffic flow characteristics; these indicators will

be compared with the scoring rules of the human observers;

- procedures will be developed to score these indicators automatically, using loop-detector data;
- human observers will score the outcomes of the automated procedure on a risk scale;
- an analysis will be carried out on these scores, to find out which traffic characteristics discriminate between the risky and not risky events, in order to refine the automatic detection procedure;
- accident types and causes will be categorized; relevant causes will be related to the situations scored as having a potential risk, in order to estimate the possible safety impact of the refined automatic detection procedure.

This procedure is supposed to result in a proto-type of an automatic detection procedure, based on traffic flow characteristics. The study is carried out with data from the A1 in Portugal, from the before period of the HOPES/PORTICO evaluation study, before the RTI-system was installed.

According to the plan, the procedure would have been repeated in the after period, if the installment of the system had not been delayed. The human observations method would have been used to evaluate the RTI-measure, as well as to check for the applicability of the automatic detection and evaluation method in the new situation.

3. TRAFFIC BEHAVIOUR, CONFLICTS, SPEEDS AND FLOWS

3.1 Introduction

As said before, the major aim of this study is to develop a proto-type of an automatic pre-incident detection system on the basis of loop-detector data. A second aim was to support the behavioural analysis of traffic disturbances, by giving detailed information about speeds, decelerations, accelerations and headways for all cars that are part of a cluster of vehicles. These clusters, containing risky manoeuvres are detected by human observers from video. This part of the work is reported in another internal HOPES report: "Incident Warning Systems: The Analysis of Traffic Behaviour". This report is mainly concerned with the development of the proto-type. It regards an attempt to derive indicators for traffic situations with increased risk, purely from loop data.

The start of this main activity was performed using computer programmes already available at SWOV. These programmes had to be adapted to the specific situation at hand. For the support of the behavioural analysis, additional software had to be developed. The following steps were taken:
- the original ASCII datafiles were merged and converted to a more manageable format;
- a programmewas developed with the following functions:
  * searching the loop data for patterns derived from video, in order to obtain synchronicity between both sets of data;
  * enabling the selection of "time slices" and producing a graphical representation of the measurements in that slice, to facilitate the analysis of traffic patterns;
  * generating several diagnostics, such that situations identified as potentially dangerous could easily be found and compared with the video pictures.

3.2 Data conversion

The original data from the DRIVE-II project PORTICO that were collected by HOPES, had an ASCII format which is generally readable, but rather cumbersome for computer processing, because of the relatively low information density.
Since several programmes to extract various characteristics from loop data (which programmes use a compact data format and can handle large amounts of data) were already available, it was decided to convert the Portico data to the same compact format.
This required two steps:
- the combination of some PORTICO data files that represented data of separate lanes over the same time period;
- the translation of the merged files into a compact format.

The problems to be dealt with were the following:
- Some of the ASCII files were distorted, both because of a changed ASCII code for some characters and a random additon of "stray" characters.
- Some of these spurious characters were of the "non printing" type and hence not easily detectable. These characters disrupted the automatic translation routines considerably.
- Eventually all ASCII files were screened manually, to get rid of these disturbances. This consumed a considerable amount of time.

After these probems had been solved, the files have been converted succesfully.

3.3 The Programme for data analysis

An extensive computer programme for IBM-PC has been developed which implements all three functions mentioned in the introduction. This program, called VERSIM, has been written in an

advanced version of BASIC for a Windows environment (CA-Realizer). The Windows environment enables the use of large amounts of internal memory and therefore the fast processing of large files of loop data.
At the same time, the graphics user interface facilitates the operation, making the rather complex programme relatively user-friendly.
The three main functions will now be discussed briefly:

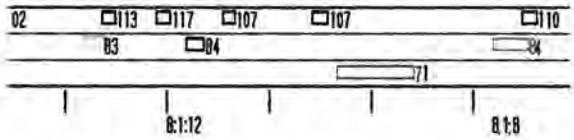
3.3.1. Pattern search facility

- Loop data and video observations, each have separate and unsychronized time registration.
- Although for both sets of data there was a reference to the "real time", still some differences have been found that made it sometimes difficult to achieve sychronization quickly. Therefore, a facility has been developed that allows the user to specify search patterns in a way that is conveniently derived from video registration. The pattern consists of an arbitrary number of vehicle data, each vehicle needing a sequence of three parameters in the pattern: passing time, passing lane and vehicle type (2 classes: passenger- or freight vehicle). Since video observation can never be very accurate with regard to time and the loop detectors are also endowed with a certain variablity, the user can specify a time interval of tolerance wich will be applied to each vehicle: usually a 2 second interval is needed.
- Another problem was, that loop detectors may miss a vehicle altogether when it happens to cover too small a portion of the loop. Therefore, the user may also specify a number of possibly missing vehicles in the pattern (just a number, no specification of position or type is needed since the programmechecks all permutations).

In practice, this pattern search facility works very well with patterns of 8 to 10 vehicles, which turn out to be sufficiently unique patterns to be found.

3.3.2. Graphical representations

- The user may also specify a certain point in time to center the time window; he may proceed to move the window in either direction. To facilitate the concurrent use of video fragments, there is a provision for temporarily changing the programme's base time, so that the displayed time coincides with the video registration.
- All vehicles that pass within the time window will be pictured on the screen, together with a specification of their speed. In this way, a graphical representation is provided of the distances *in time* between those vehicles in the window and also of their length *in time*.
- This picture may differ considerably from the *spatial* distances and lengths, which observers are used to, when they observe a video recording. Therefore an optional second picture can be generated in addition, depicting an estimate of the spatial distances and lengths in the same time-window. These distances are estimated on the assumption that all vehicles in the window maintained or already had the speed that was measured when they passed the loops.



Example I

Since the window generally has a time-length of 8 seconds this assumption may not be entirely correct (for the PORTICO project we could assess the correctness of this assumption by using the data of the second pair of loops 20 meters downstream, but this has not been done yet). The windows shown on the screen can also be printed for documenting purposes (see Example I).

During the development of this part of the programme, an important difference was discovered between the system used by HOPES and Dutch systems of loop-measurements: where the HOPES system seems to log the passing time of vehicles from the onset of the measurement, the Dutch systems logs them at the end. Depending on the length and speed of the vehicle, the difference between the two procedures may be up to 1 second.
Although this poses no real problem, the programme has been extended with an option to specify the type of registration, in order to avoid difficulties.

3.3.3. Diagnostic facilities

- As stated before, SWOV already possessed programmes to derive various traffic characteristics from loop data. These programmes however, operate on the basis of averaged parameters and so provide insight into the changes of various safety-related traffic flow parameters. Although the combined outcomes may also be of interest for the PORTICO incident detection system, in this study these were primarily used to detect single events in the traffic stream that may be considered potentially dangerous.
- The programme VERSIM is therefore equipped with a facility to scan the whole data file, or a specific portion of it, for such specific events on a vehicle by vehicle basis and to log them in a separate file.
- This log-file is formatted such, that the data may easily be used to retrieve the corresponding video fragments for further analysis.

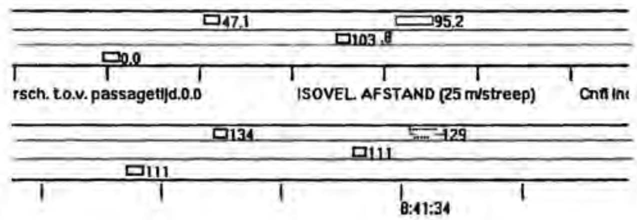
3.4 Loop data analysis

This part of the programme is largely based upon the results of the video data analysis. This analysis resulted in the definition of a number of potentially dangerous events, part of which can also be inferred from loop data. So far, six types of event are recognized by the programme. Four of these events regard subsequent vehicles in a single lane, the other two events regard interference of vehicles in adjacent lanes. We like to stress that the (numerical) criteria for each event do not have a very solid basis yet. In fact we expect that only preliminary results can be reached and that a more firm basis must be provided later on. Firstly, the values of the indicators will be compared to the scores for the same situations by trained human observers. Finally these incidators have to be compared to incident and non-incident data from actual traffic situations.

3.4.1 Definition of incidents

The four single-lane events are:

- TTC warning: this is scored when the hindmost of two vehicles is the faster and without any action collision is imminent within a specifiable time interval which is by default set to 2 seconds. This criterion accounts for *relative speed and proximity* and is only active when a speed difference exists.
- Emergency braking: this criterion considers *proximity and reaction time* and works also when two vehicles have the same speed. Here, we suppose that the leading vehicle of a pair suddenly executes an emergency breaking manoeuvre with an average decelleration of 6 m/s2. We further assume that the driver of the following vehicle will have a certain reaction time (adjustable, but defaulted at 1 second) in which the speed of his vehicle does not change. We then calculate whether or not the second vehicle will collide with the first within this reaction time period.



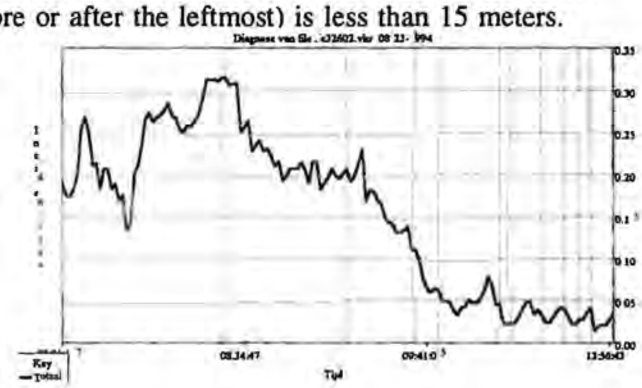
Example II : False freight vehicle

- Pushing: this criterion actually weighs the same phenomena as the TTC criterion but in a simpler way: it reports an event when two vehicles are closer to each other than a specifiable distance (default 4 m) and some positive speed difference exists. Other than TTC, which may report an incident with far larger distances but greater speed difference, this criterion signals mainly very close proximity. We discovered however that, where the Dutch system seems to be able to discern vehicles that pass the loops with a distance shorter than the length of the pair of loops, the PORTICO system cannot. Instead, a single, long vehicle is reported. Therefore, a fourth criterion was introduced:
- The "false freight vehicle": if a vehicle longer than 8 meters is reported on the middle and leftmost lane, having a speed in excess of 30 m/s, it is assumed to be falsely reported as a freight vehicle, but instead must be interpreted as a close pair of passenger cars (see Example II).

The two other events, which assume interaction of vehicles in adjacent lanes are:

- Overtaking on the wrong side: this criterion is activated if a vehicle in a certain lane has a significantly greater speed (>4 m/s) than a vehicle in an adjacent left lane, while at the same time the distance between the vehicles (before or after the leftmost) is less than 15 meters.
- Simultaneous encroachment: this is an interaction between 3 vehicles and occurs when two vehicles in adjacent lanes encroach upon a third (in the rightmost lane of the two) that, if no action is taken, the three vehicles will eventually end up trying to occupy a space suited for only two of them.

  Since this criterion is based upon the assumption of unchanged speeds and as this assumption becomes progressively weaker with elapsed time we have limited the extrapolation period to 10 seconds.



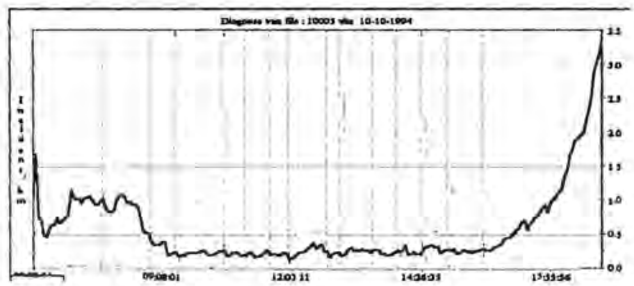
Example III

ANNEX I gives an example of a traffic disturbance as represented by the VERSIM programme that was scored by human observers from video as a behavioural disturbance as well as a conflict.

Lastly, the programme provides some statistics regarding the reported incidents: the number of incidents is averaged over time as well as the traffic flow and these data are incorporated in the diagnostic outputfile.

With the aid of a separate program, called INCIDEX, we can display graphs of the average frequency of incidents (the "incident density" in incidents per second; see Example III).
Since this frequency-indicator is rather strongly correlated with the average traffic speed, a second indicator is produced, weighing the incident density with average speed, so providing a *speed-independant characteristic*: the number of incidents per m. As this is usually a small number, the incidents per km is presented.
It is also possible to produce graphs depicting the relative contribution of all types of conflict, thus diagnosing the predominant conflict at a certain time or a certain location.
The incident density is calculated while taking into account that a single vehicle can be part of more than 1 conflict; if these are conflicts of the same nature (TTC, pushing, etc.) we count its contribution to the tally of conflicts for only one.

For the calculation of the moving averages we have employed a scheme that was developed for previous diagnostic programs: a modified discounted least squares scheme that can accomodate non-equidistant data (since incidents do not occur at regular time intervals).



Example IV

3.4.2. Parameters

It should be pointed out that instead of the "classical"parameters: flow, density and average speed, SWOV prefers to use parameters that account for the length of the passing vehicles as well. There are several reasons for this choice, that seems to deviate from "mainstream" traffic theory:

- A traffic process, as seen from the point of view of any of its participants, is predominantly a *spatial* process; participants act upon observations of relative position and speeds and of the space available for manoeuvring. The decisions and actions they take on the basis of these observations directly determine if a local traffic process will be safe or whether an incident takes place. Hence, if we want to study or influence traffic safety, we had better choose those characteristics that correspond most closely to the parameters that road users employ to determine their behaviour.
- The length of a vehicle plays an important part in estimating it's potential for acceleration and deceleration and it's manoeuvrability and also the total mass of the vehicle (the difference between passenger cars, vans, trucks and busses). These characteristics, amongst others, strongly influence the types and results of conflicts and accidents that the vehicles may be involved in.
- The characterization of the traffic status per lane by using flow and density is often misleading due to the uneven distribution of long vehicles over the lanes: these parameters often show large differences between lanes thereby suggesting inefficient distribution of traffic over the lanes. The actual space occupied by vehicles in each lane however is usually much less different (the number of vehicles in the right lane is smaller than that in the other ones, only the vehicles are on the average much longer). Parameters that intrisically account for vehicle length do not allow this misinterpretation.

For these reasons we substitute density (veh/m) with occupancy (m-veh/m) and flow (veh/s) with "production' (m-veh/s) and calculate the weighed average speed from the quotient of these two. The latter has the effect of slightly emphasizing high speeds if the vehicle length is also large: thus the average speed is slightly biased towards the speed of longer vehicles.
Apart from those, a score of other parameters is calculated by standard software of SWOV like average headway and gap, average speed difference between successive vehicles etc. Also the variation coefficient of the gap is calculated. These last two parameters can be interpreted as different measures of "regularity" in traffic. Higher average speed difference in this respect can be interpreted as more "unrest" provided that the average production does not change strongly. The variation coefficient of the intervehicular gap indicates whether the traffic is evenly distributed along a lane or carriageway (low values: <=1) or whether this distribution is clustered (higher values:>>1).
These parameters have been used for a first characterization of the Portico traffic situation: for every day of observation we have produced graphs depicting the variation of average speed, production, occupancy as well as average variation coefficient, speed difference and the fraction of freight vehicles (length > 6 m) with elapsed time.

3.5 Results

3.5.1 General characteristics of traffic flows

Some basic, normally slowly changing characteristics are specified. To do this, filtered signals have been employed. The filter used here has a time constant of approximately 600 seconds. ANNEX II gives the outcomes of these analyses and a description of the Dutch terms in the figures.
Figure 1 through 30 show several characteristic parameters derived from the PORTICO loop data. There are 6 graphs for each day of observation and the time intervals more or less coincide with the hours of video observation. All parameters are defined *per lane* and identified as follows:
1: leftmost lane, 2: middle lane and 3: rightmost lane. At points where the measurements are interupted, the averaging procedure of the measurements becomes unstable. This is an artefact of the computing algorithme. Measurements need some period of time for the curves to become stable again.
Next, general tendencies over the day are described. If we consider the graphs, we find that the average speed increases slightly over the day (ca 1 m/s) and that there is a rather large speed difference between lanes 3 and 2 of 5 m to 7 m/s and between lanes 1 and 2 of ca 5 m/s. The maximum production is 1.5 m-veh/s, round 8 o'clock, and decreases gradually.
The same is true for the lane occupancy, which is highest at ca 6%. The percentage of freight vehicles, that is vehicles over 6m in length, per lane is relatively high on the rightmost lane: always higher than 40% but often 60%. Although freight vehicles are often considered an obstacle to passenger cars, the total of characteristics indicates no serious traffic conditions: capacity is never reached (as would be indicated by a decrease in average speed). There are, however, some remarkable features shown by the graphs of the absolute speed differences (dV absolute) between successive vehicles in one lane: the average speed difference in all lanes is at least 2.5 m/s and increases toward noon to 4-5 m/s. The higher speed differences are apt to induce more frequent speed adjustments, making the traffic pattern less predictable and therefore theoretically less safe, so we could infer that there is a tendency towards increasing risk over the observation period. This tendency however, is offset by a gradually decreasing production and occupancy which influences the frequency, making the conclusions less "straightforward" (see "event analysis").

Another characteristic, the variation coëfficient of gaps, which varies around the value of 1, indicates that over most of the observation period the traffic is more or less Poisson distributed and not strongly clustered (which would result in a much higher variation coefficient). There is a remarkable "gap" in the period between 11h and 13h in which the traffic density suddenly seems to decrease drastically for about 10 minutes. Such a sudden change is probably caused by an artifact in data collection (e.g. a change of recording media, interrupting the measurements) which the video observations seem to corroborate.

Comparison to a "known" situation
In the figures 31 - 36 data are assembled of a Dutch motorway (A13) which has a configuration comparable to Portico. This motorway constitutes an important link in the "Randstad" network in Holland. Generally speaking, the level of safety on this road is not significantly different from other Dutch motorways, which means that accident rates are low. If we compare the characteristics of this motorway to those of Portico, we find some differences:

- the difference between average speeds per lane is larger in the Portico data: theoretically (if all other parameters were equal) this would make lane changing a little more difficult and hazardous than in the Dutch situation;
- the variation coefficient of intervehicular gaps shows only minimal differences between the two: traffic is always more or less evenly distributed;
- the Portico situation consistently shows a considerably higher percentage of freight vehicles in the right lane, which probably accounts for the higher differences in average speed between lanes.

The latter could imply a somewhat higher level of risk but this conclusion is offset by the generally lower production and occupancy, which on the average suggests more space between vehicles.
However, since the marked increase of average speed difference is accompanied by a decrease in production, we can not decide that the Portico circumstances are actually more risky than the Dutch one. All in all, the comparison provides no clear motive to consider the Portico circumstances as fundamentally different from the Dutch one, implying that both situations are relatively safe.

3.5.2. Event analysis

We now refer to Figure 37 through 50. These figures contain the results of the INCIDEX programme, described in the previous paragraph. They show a general tendency towards a decreasing average number of "critical events" over the observation period. The incidence of these events is highest in the period between 8h and 9h30 and considerably lower in the later period. Contrary to the general speed difference characteristic, this suggests that the earlier period must be considered as having the highest risk. Since the general speed difference does not account for distance between vehicles and the event analysis does, we are inclined to have higher confidence in the latter.
There remains the problem, however, of determining which frequency of events must be considered grounds for corrective actions. So far, we have no reference in "real accidents" to establish such a limit (or area of unacceptable risk). However, during the observation period on the Dutch motorway, an accident took place close to a measuring site. The accident took place at 16h, during the evening rush hours, at a distance of ca 50m from a loop station. In figures 49 and 50 the change in event frequency at that loop station is shown in the 15 minutes prior to the accident: we find a change from 0.15 to 0.5, which maximum is twice as high as the maximum frequency during the morning rush hours. Of course, this one result is no real basis for firm conclusions, at most an indication that at frequencies of around 0.5 or higher an accident seems somewhat more likely. In the PORTICO measurements we generally find maximum values well below 0.5 except for one day where a value of 1.5 occurred for a few minutes (but no accident took place!). So, also on the preliminary basis of this criterion, the Portico situation must be considered as relatively safe

or at least not observably different from a site which is known to be relatively safe.
To establish a better insight into the practical value of the event-frequency indicator more and longer term observations and correlations with accident data are needed; in the meantime, this indicator seems intuïtively promising.

3.5.3. Comparison of automatic loop-detector scoring and video scoring

A first comparison has been made between the automatic scores by the INCIDEX system and the scoring of the same events by human observers from video.
Because of the difficulties to synchronize the data and to read video times, only part of the data has been compared. This regards the video recordings of November 22, November 24 and part of November 25.
Table 1 shows the results. In total 173 automatic detected events were scored by a human observer. 131 of these events were considered not to be risky disturbances. 28 events were scored with low risk, 15 with high risk. The major amount of events (81) considered as not risky were scored with the "encroachment" criterion. This criterion needs serious adaptation. On the other hand, 7 events were detected with this criterion as being risky. Therefore, a deletion of this criterion is not recommended. There are also many overtakings-to-the-right that are scored as not risky. However, a considerable amount of events with low risk are detected as well. Therefore, the criterion can be included. Because of the low risk involved, the total number could be corrected with some weight factor, before the criteria are combined. The same counts for the pushing indicator. The false freight indicator as well as the TTC-indicator seem also relevant indicators with regard to risk.

Table 1. Comparison of automatic incident detection from loop-detector data and video scores by human observers.

Incident criterion	no risk	low risk	high risk
TTC	4	4	3
Pushing	5	3	-
Emerg. braking	4	2	1
Overt.-to-the-right	18	11	1
Encroachment	81	4	3
False Freight veh.	13	3	5
Combination	6	1	2
Total	131	28	15

LITERATURE

[1] Carsten, O. 1993 (ed). Framework for Prospective Traffic Safety Analysis. HOPES Deliverable 6. Department of Traffic Planning and Engineering, University of Lund.

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GLOSSARY

IWS
Incident warning system; to warn road users for accidents ahead, congestion or slow driving vehicles, obstacles on the road, etc.

Accident analysis
Traffic safety analysis, based on recorded accidents, to detect the combination of factors that caused the accident.

Accident rate (Fatality rate, Injury rate)
The number of accidents (fatalities, injuries) devided by a measure of exposure to risk, such as the number of vehicle kilometres.

Accident review
Description of the recorded accidents by type and or cause.

Accident risk
The expected total loss resulting from expected numbers and types of accidents, for a nation, person, vehicle, route or location. In its simplest form it is measured by using the accident rate.

Behavioural analysis
Analysis of road user behaviour, in particular of potentially dangerous behaviour (risky overtaking, close following, cutting in, fast approaches, unexpected or late manoeuvres, swerving etc.).

Conflict analysis
Specific type of behavioural analysis, in particular of potentially dangerous interactions between road users, that would have resulted in an accident, if no quick evasive action had appeared.

Disturbance
Traffic situation in which one of the drivers does not adapt his behaviour adequately, putting him or herself or other road users in danger, or behaves otherwise unexpectedly, e.g., by violating the traffic rules, with or without interrupting the normal traffic process.

Evasive action
An observable manoeuvre, e.g., braking or changing lanes, carried out by a road user to decrease or remove the potential risk caused by a disturbance.

Intermediate measure
A measure of potential danger, derived from road user of risk behaviour, in relation to the state of the traffic system and the road user environment.

Potential risk
A traffic situation in which one or more road users have such limited possibilities for manoeuvring, that in case of a disturbance or unexpected manoeuvre, an accident can hardly (or not) be avoided by one or more of the traffic participants involved.

Risk score
A subjective scale to score the risk of a disturbance based on the presence of e.g. the following conditions:
- short headway;
- number of manoeuvres necessary to decrease risk;
- complexity; number of participants and/or number of lanes occupied by participants involved.

ANNEX I. VERSIM REPRESENTATION OF A DISTURBANCE

Example of VERSIM output of a scored disturbance for the first and second pair of loops.

The top picture is concerning distance. "isoveloxische afstand" means isoveloxic distance (estimated distance from loops with constant speed). The values for each car (box) are the headways in metres.
The bottom picture is the same but with regard to time in seconds. The values for each car refers to the speed.

The disturbance, was scored by LUND as a conflict. SWOV scored the disturbance as pushing, with high risk and reactions of others; it is a complex situation: two cars on the left lane, one car and one lorry on the right lane; three manoeuvres are scored: on the left lane pushing and braking, on the right lane overtaking to the left.

For this example, the scoring of the disturbance was corrected on the basis of the VERSIM pictures. On the other hand it turned out that a proper interpretation on the basis of traffic stream characteristics from one or two loops only is not always possible. However, in simple situations, regarding close following and pushing or approaching with high speed with or without manoeuvring space for that car or the one in front, most of the critical events can be already detected. Further investigations, preferably on the basis of image processing or data from several loops, are necessary to improve the automatic detection of risky traffic disturbances and conflicts.

The picture also shows an example of a "false freight vehicle" on the left lane and an "unrealistic vehicle length" on the middle lane.

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Traject : 8
Animatiestap 20

TTC grens : 2
Opdruk afstand : 4
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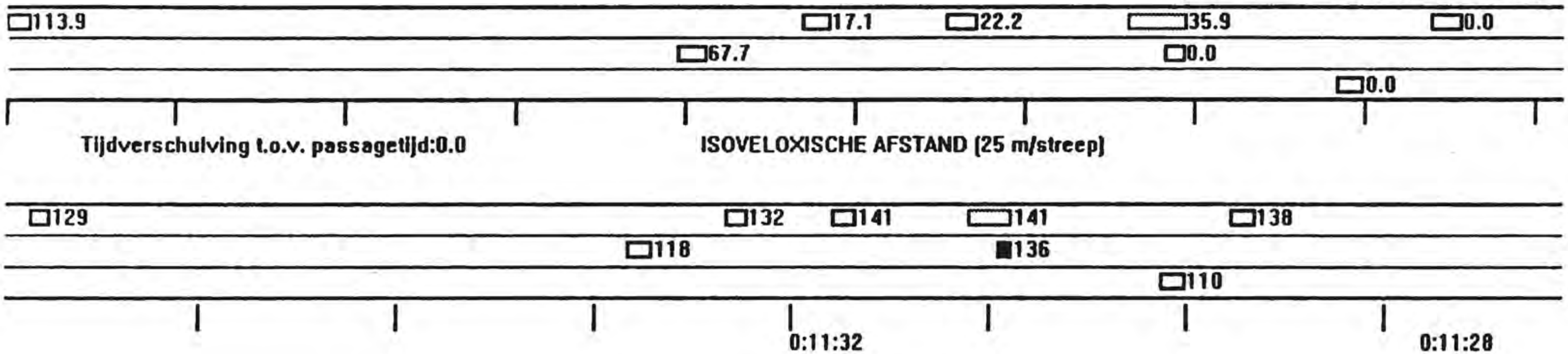

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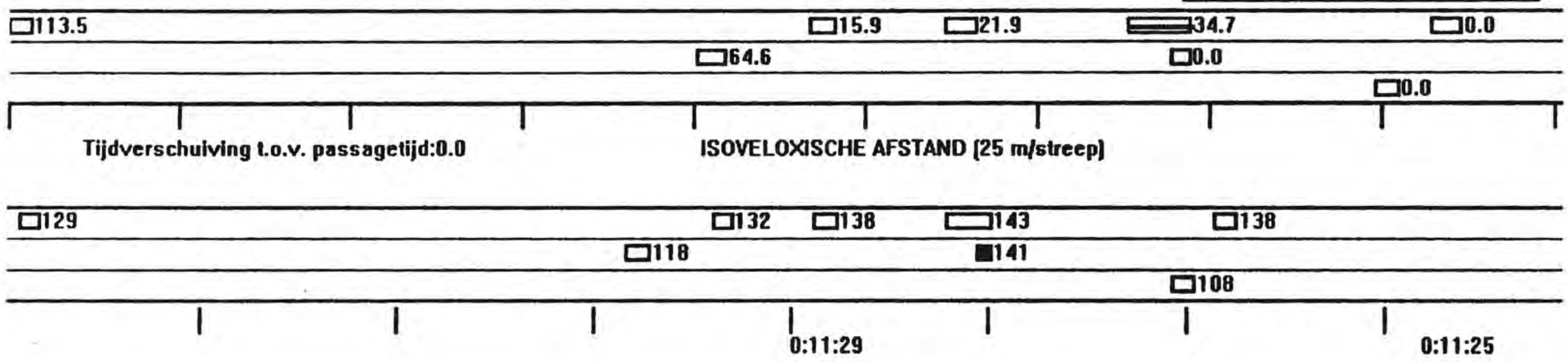

ANNEX II. INCIDEX OUTPUT

There are 6 graphs for each day of observation. The time intervals more or less coincide with the hours of video observation. All parameters are defined *per lane* and identified as follows:
1: left lane, 2: middle lane and 3: right lane. At points where the measurements are interrupted, the averaging procedure of the measurements becomes unstable. This is an artefact of the computing algorithme. Measurements need some period of time for the curves to become stable again. The following parameters are visualised:

1. "V-gewogen" (weighted speed: weighted according to vehicle length) in road metres per second;
2. "Var. Coeff. volgtijd" (Coefficient of variation of intervehicular gaps, in same lane);
3. "Aandeel vrachtverkeer" (Rate of freight vehicles);
4. "dV absoluut" (absolute values of intervehicular speed differences in same lane) in metres per second;
5. "Productie" (production: passing vehicle length per second, instead of number of passing vehicles per second)
6. "Bedekkingsgraad" (occupancy) in vehicle length in metres, per road length in metres)'.

By definition: "Produktie" = "Bedekkingsgraad" x "V-gewogen"

General tendencies over the day are described. Looking at the graphs, we find that the average speed increases slightly over the day (ca 1 m/s) and that there is a rather large speed difference between lanes 3 and 2 of 5 m to 7 m/s and between lanes 1 and 2 of ca 5 m/s. The maximum production is 1.5 m-veh/s, round 8 o'clock, and decreases gradually.
The same is true for the lane occupancy, which is highest at ca 6%. The percentage of freight vehicles, that is vehicles over 6m in length, per lane is relatively high on the rightmost lane: always higher than 40% but often 60%. Although freight vehicles are often considered an obstacle to passenger cars, the total of characteristics indicates no serious traffic conditions: capacity is never reached (as would be indicated by a decrease in average speed). There are, however, some remarkable features shown by the graphs of the absolute speed differences (dV absolute) between successive vehicles in one lane: the average speed difference in all lanes is at least 2.5 m/s and increases toward noon to 4-5 m/s. The higher speed differences are apt to induce more frequent speed adjustments, making the traffic pattern less predictable and therefore theoretically less safe, so we could infer that there is a tendency towards increasing risk over the observation period. This tendency however, is offset by a gradually decreasing production and occupancy which influences the frequency, making the conclusions less "straightforward" (see "event analysis").
Another characteristic, the variation coefficient of gaps, which varies around the value of 1, indicates that over most of the observation period the traffic is more or less Poisson distributed and not strongly clustered (which would result in a much higher variation coefficient).

If we compare the characteristics of a Dutch motorway (A13) to the motorway of Portico, we find some differences:

- the difference between average speeds per lane is larger in the Portico data: theoretically (if all other parameters were equal) this would make lane changing a little more difficult and hazardous than in the Dutch situation;
- the variation coefficient of intervehicular gaps shows only minimal differences between the two: traffic is always more or less evenly distributed;
- the Portico situation consistently shows a considerably higher percentage of freight vehicles in the right lane, which probably accounts for the higher differences in average speed between lanes;

The latter could imply a somewhat higher level of risk but this conclusion is offset by the generally lower production and occupancy, which on the average suggests more space between vehicles. However, since the marked increase of average speed difference is accompanied by a decrease in production, we cannot decide that the Portico circumstances are actually more risky than the Dutch one, both motorways seem relatively safe from these general indexes.
The critical events as produced by the INCIDEX programme are also given. The final figures regard the Dutch example including the accident.

INCIDENT-ANALYSE

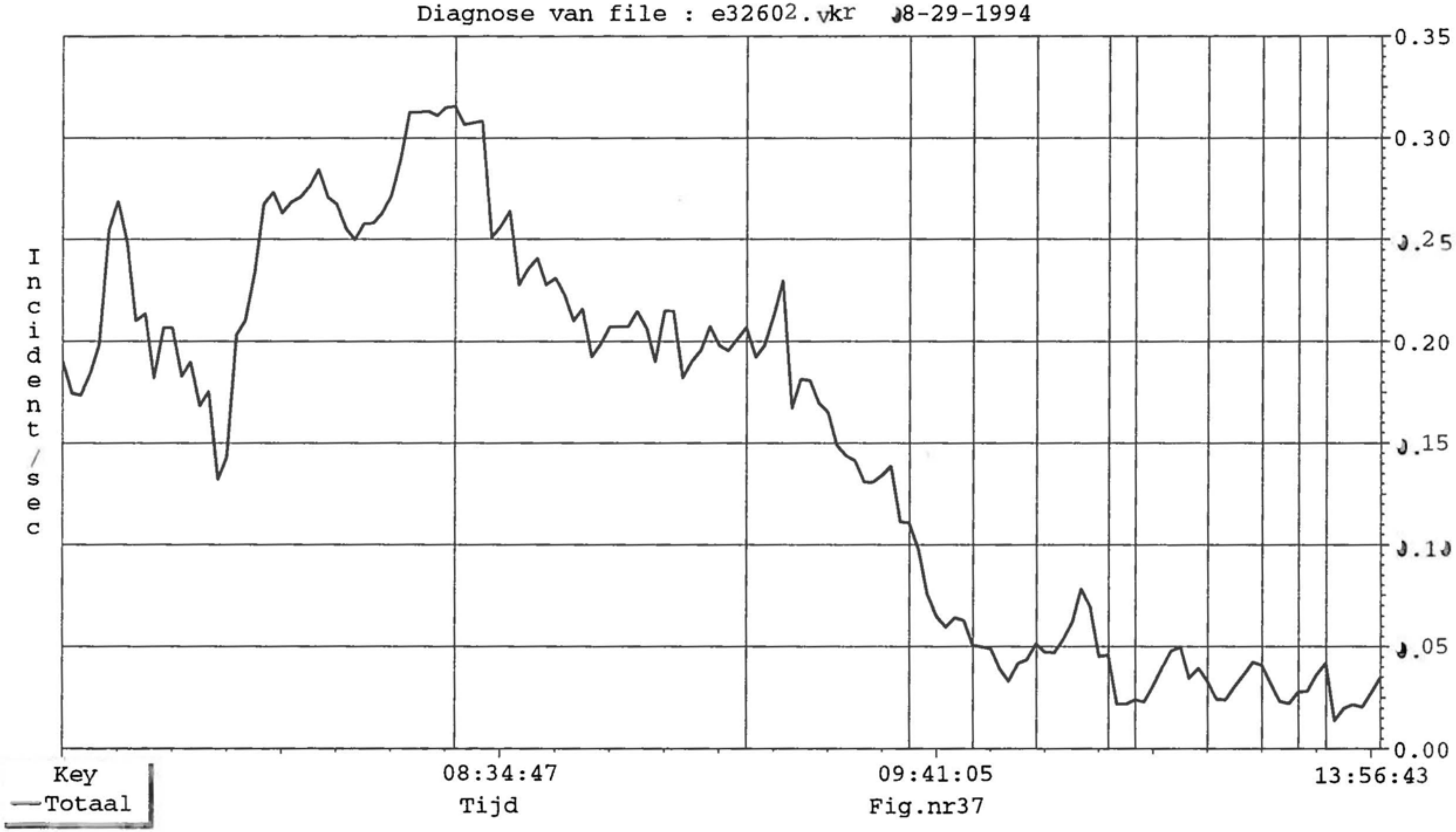

Fig.nr37

INCIDENT ANALYSE

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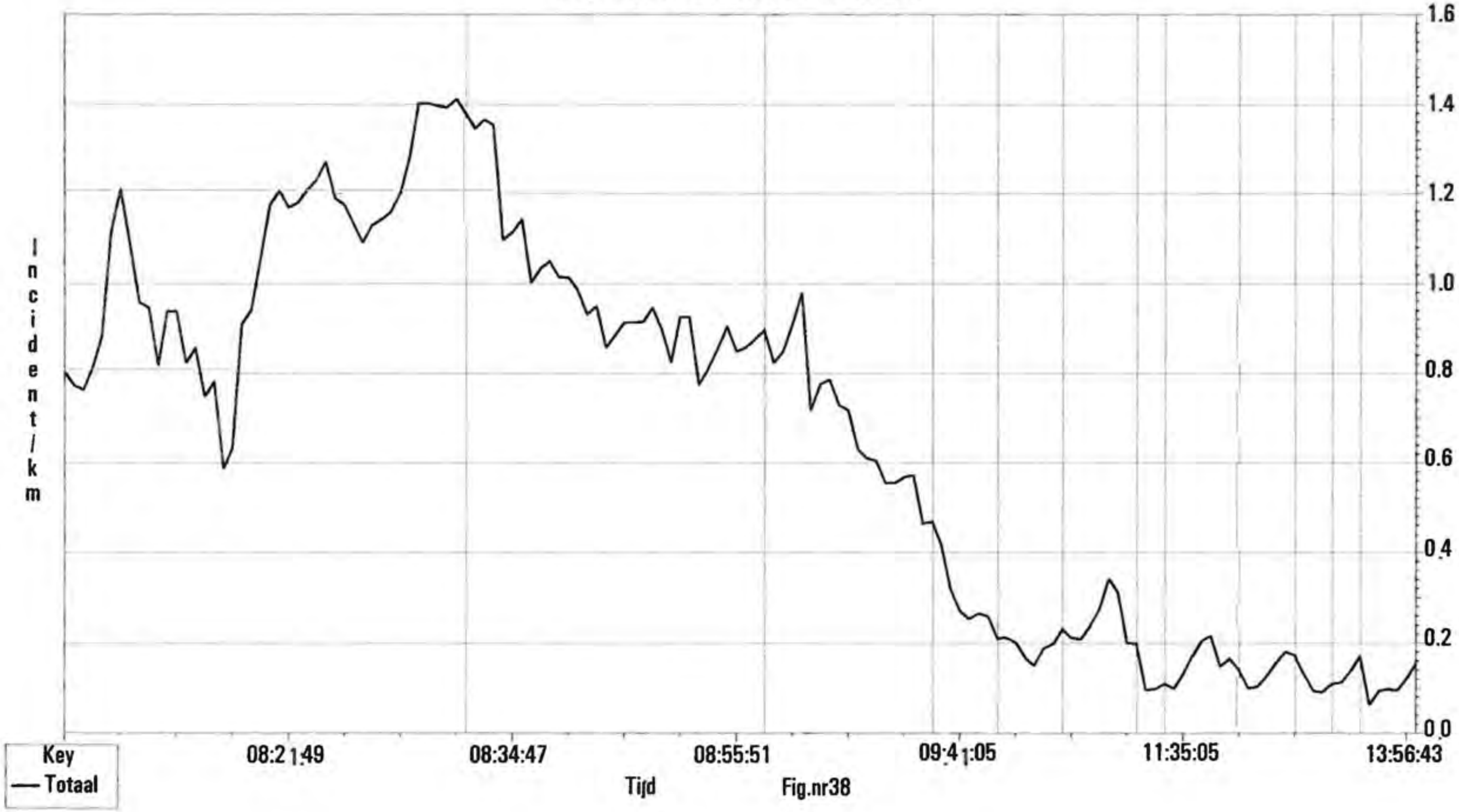

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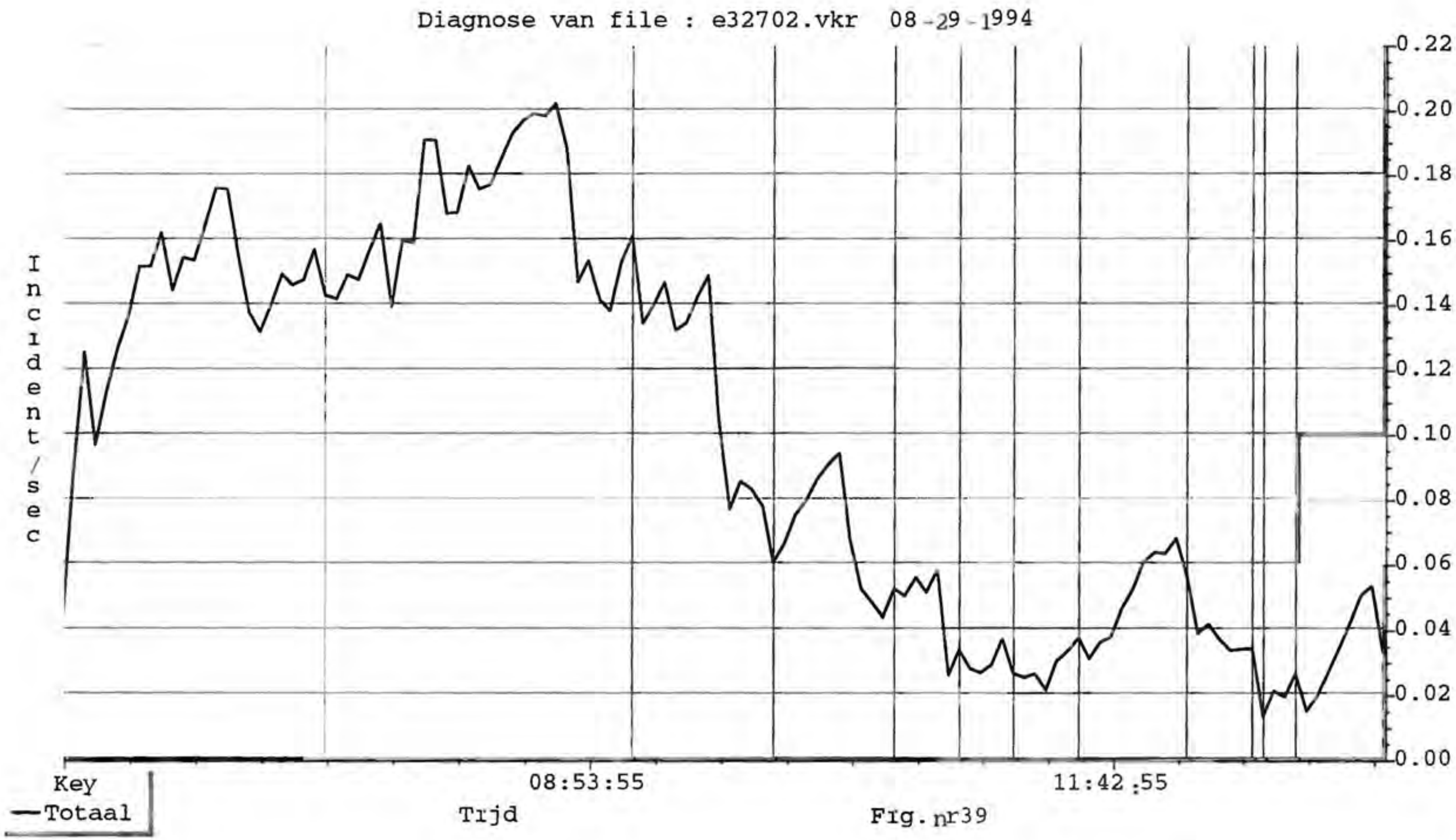

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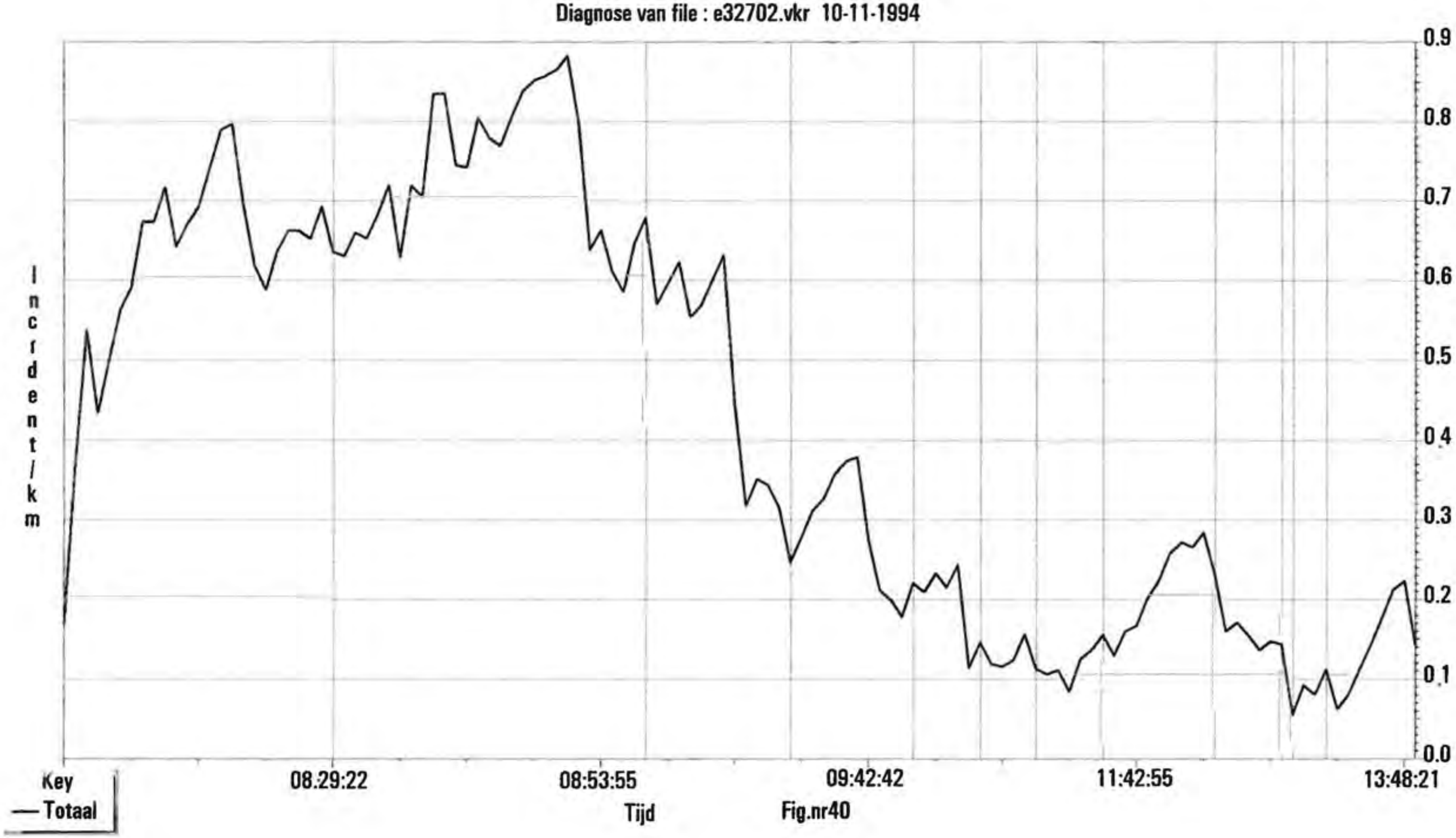

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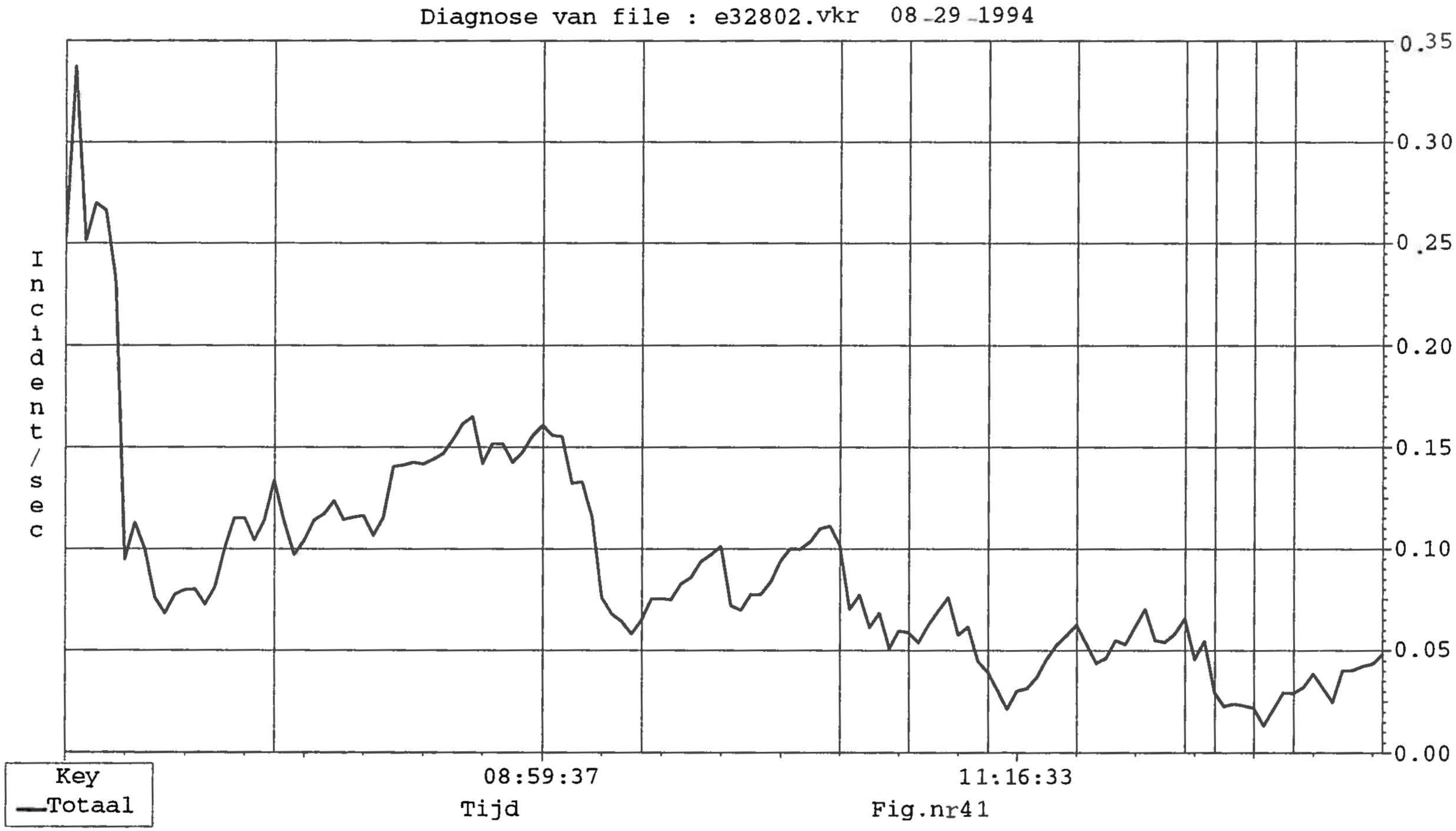

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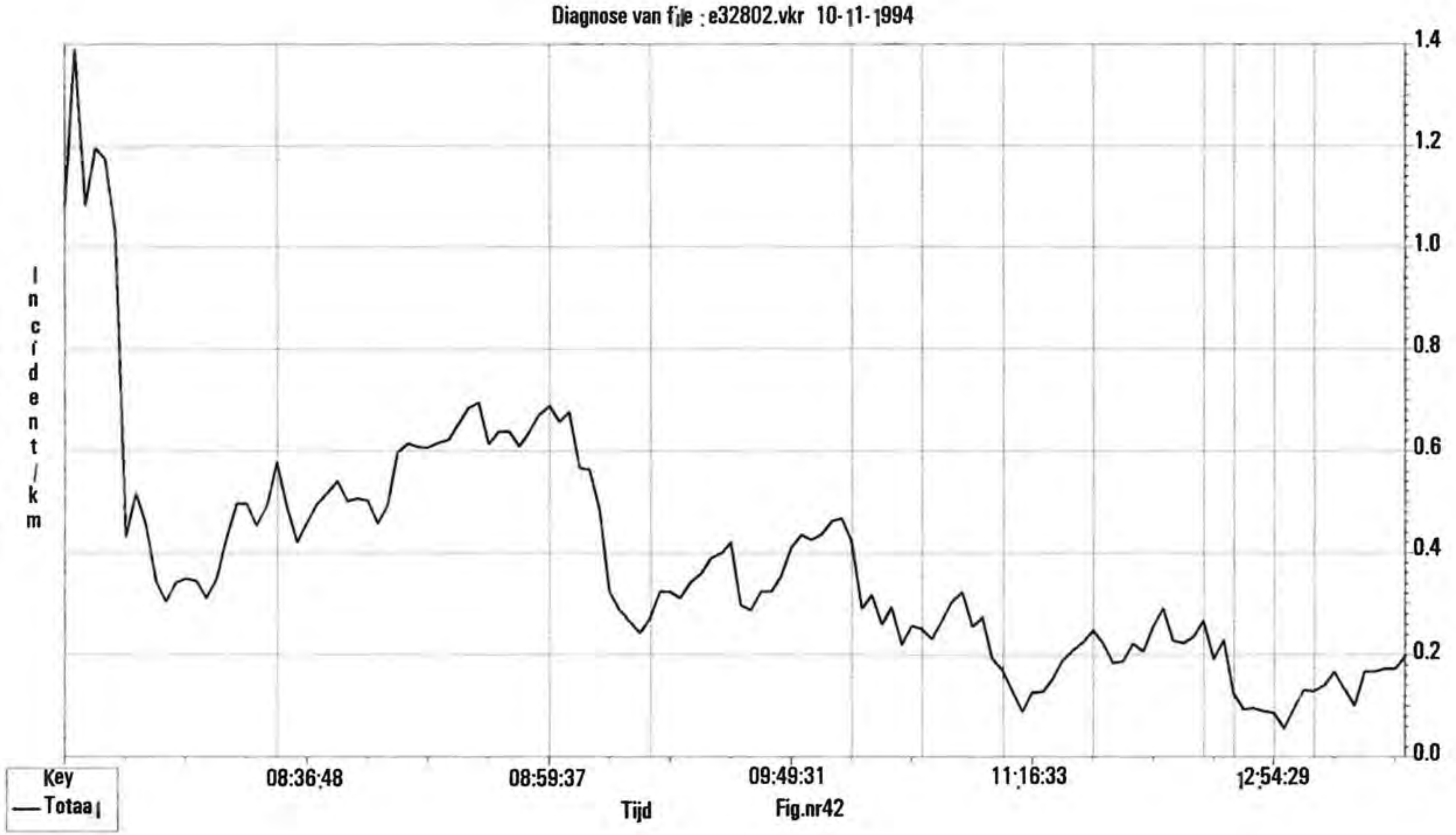

Fig.nr42

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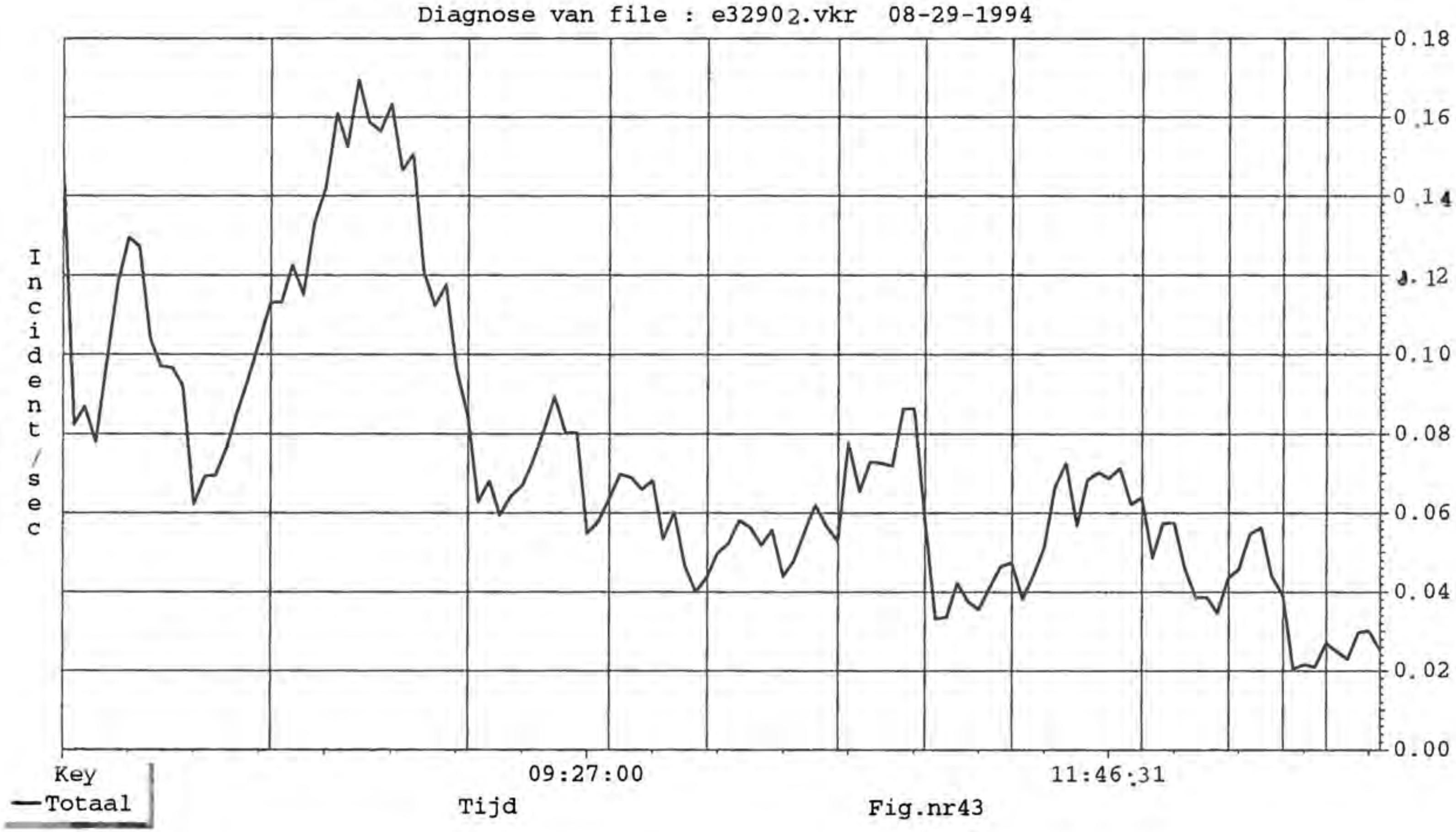

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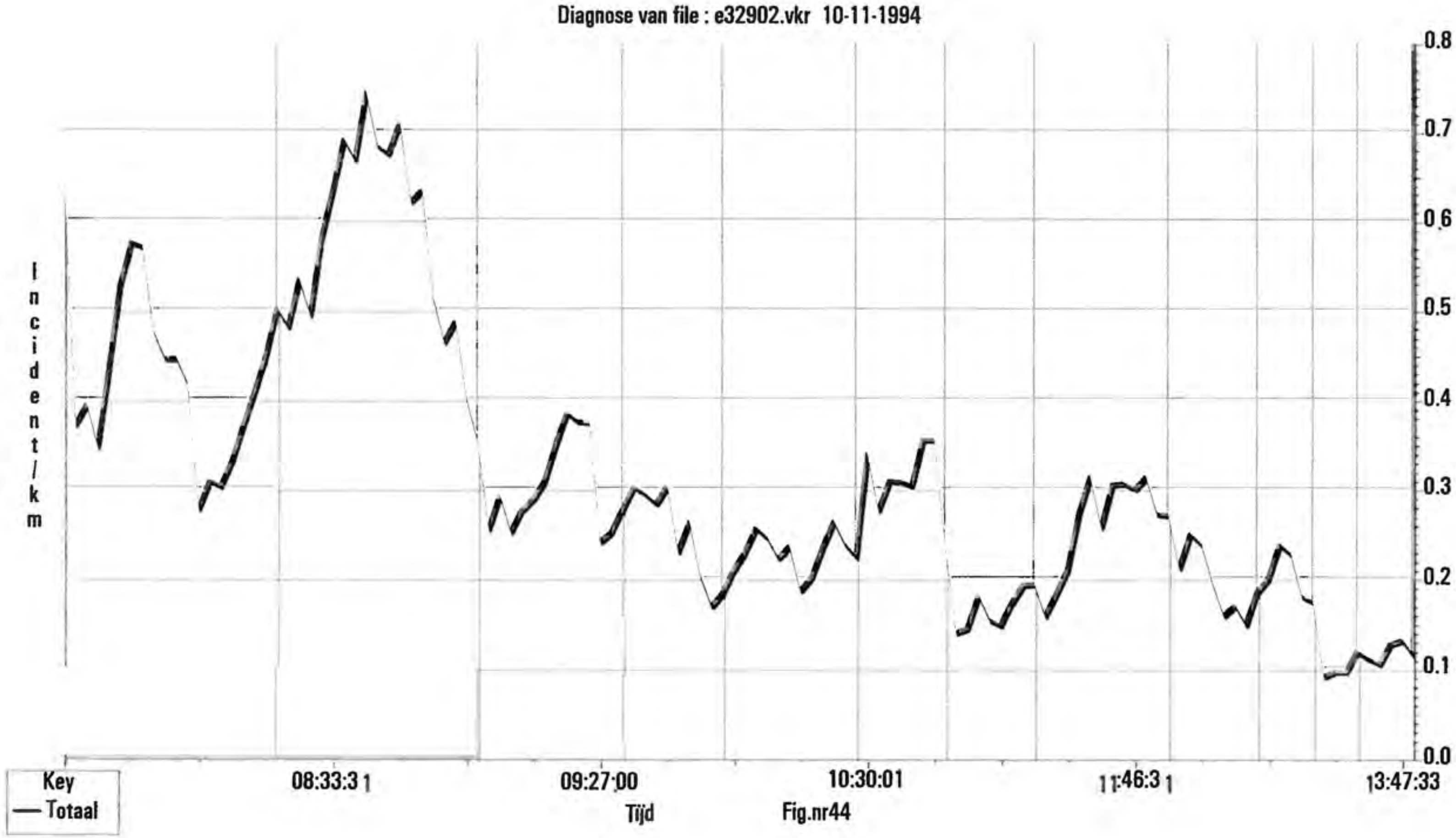

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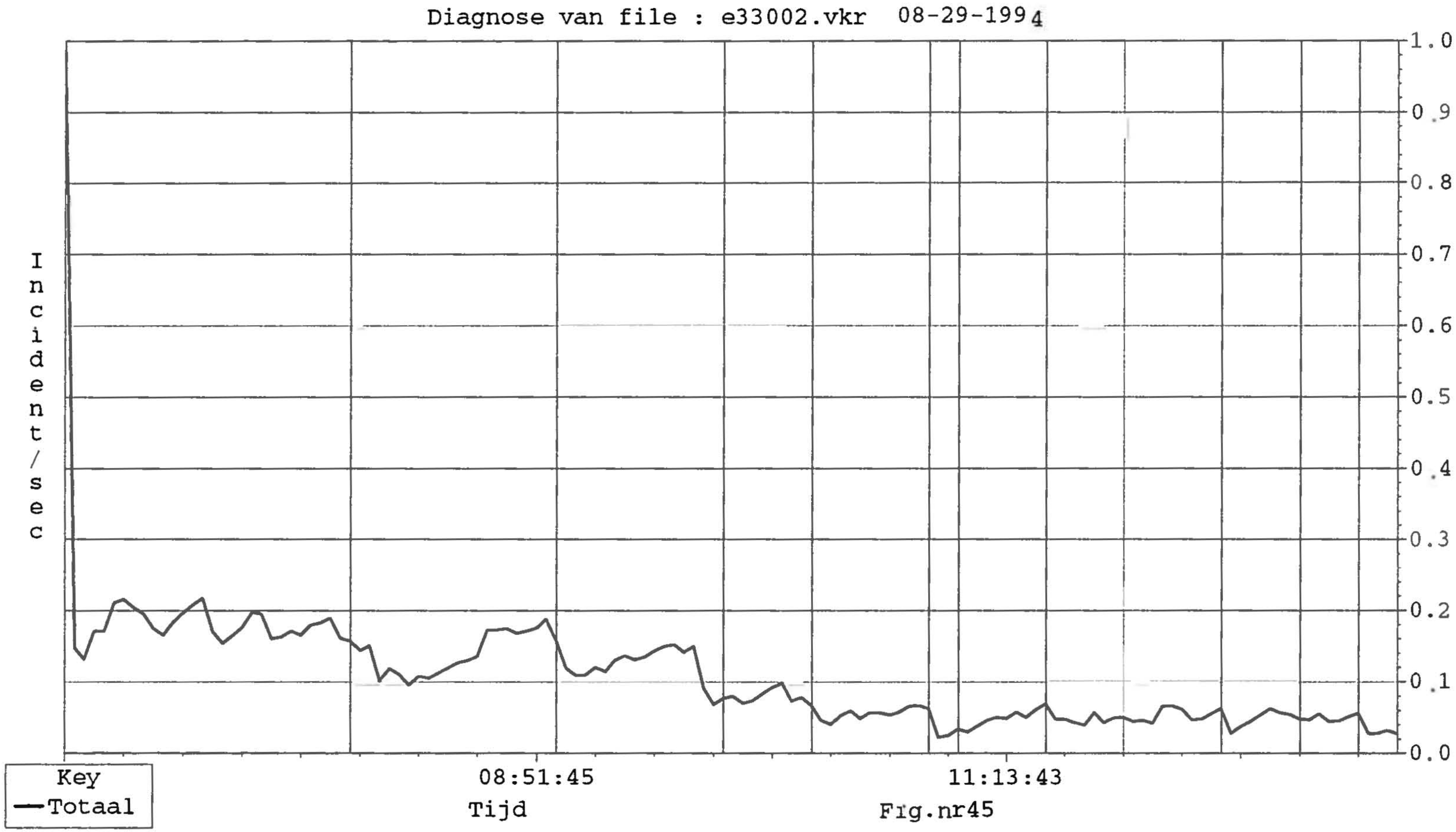

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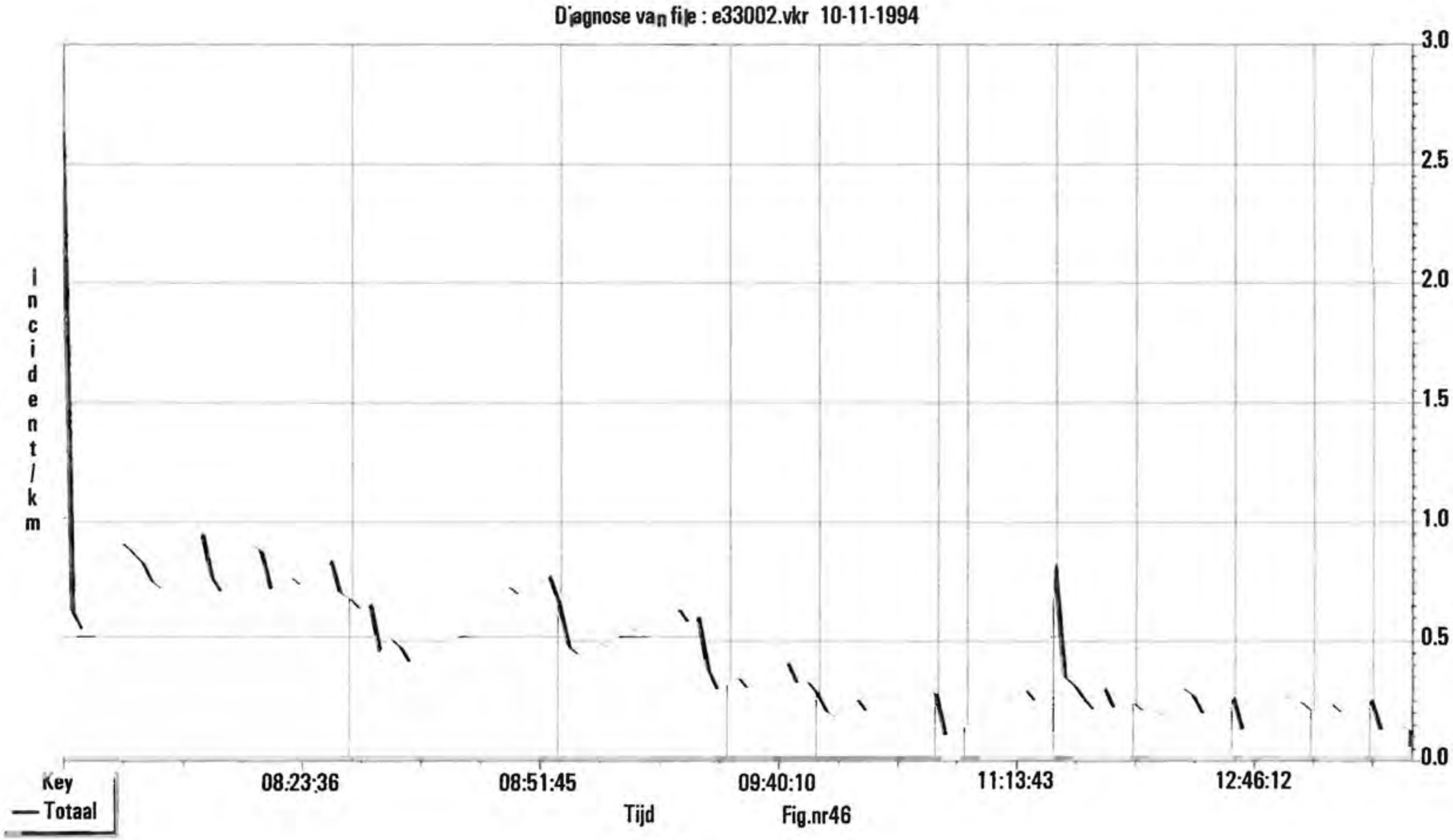

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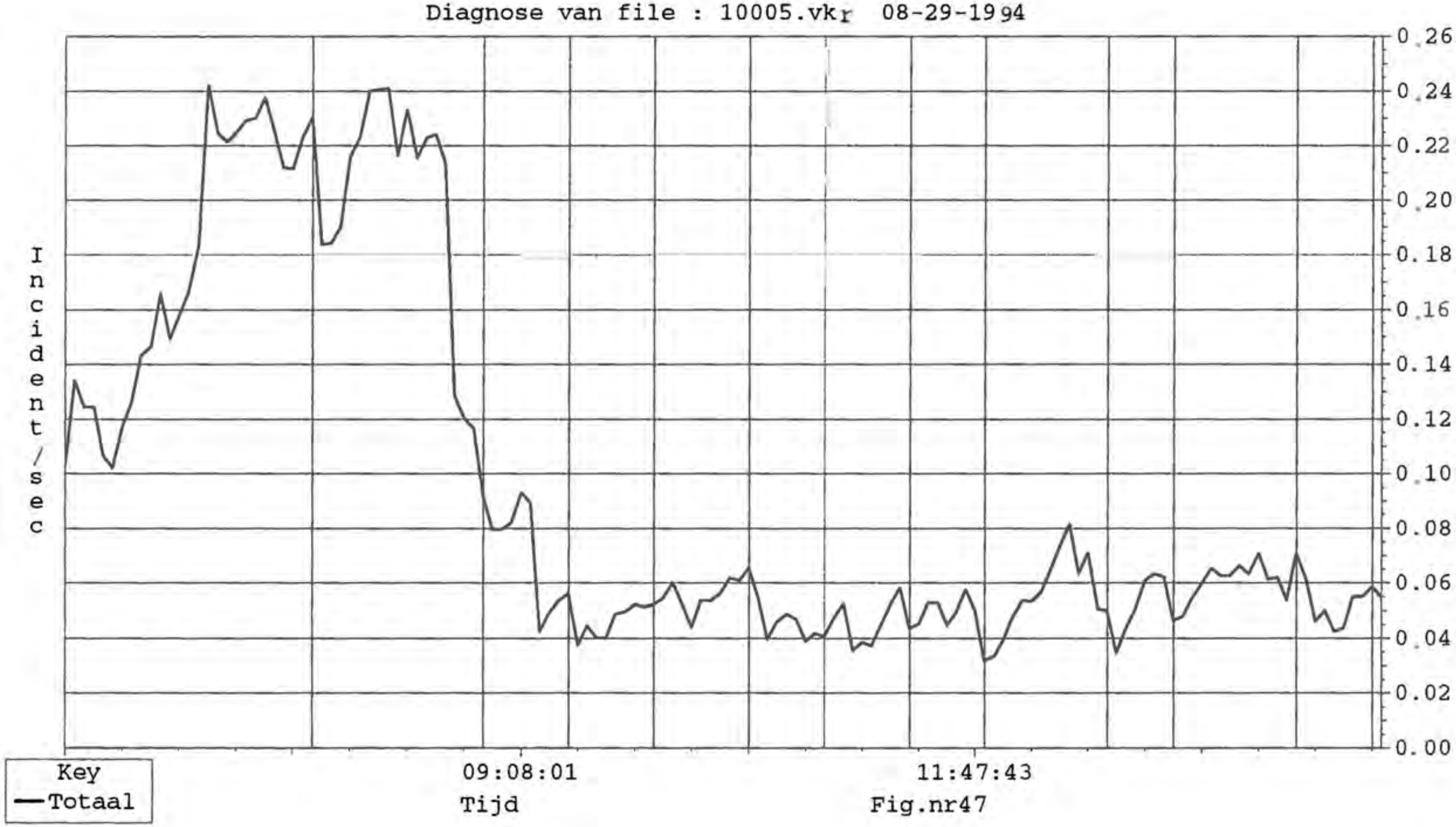

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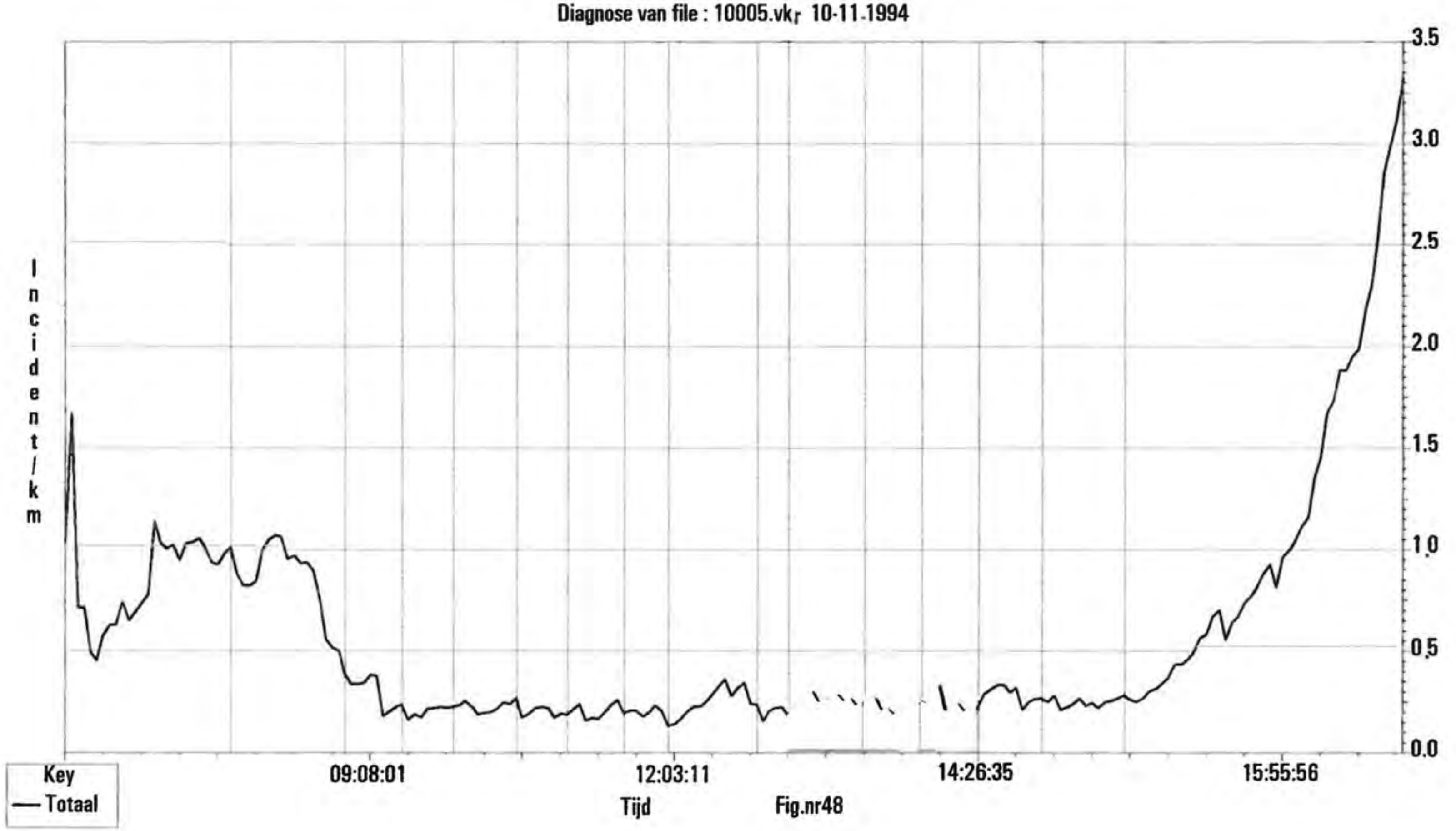

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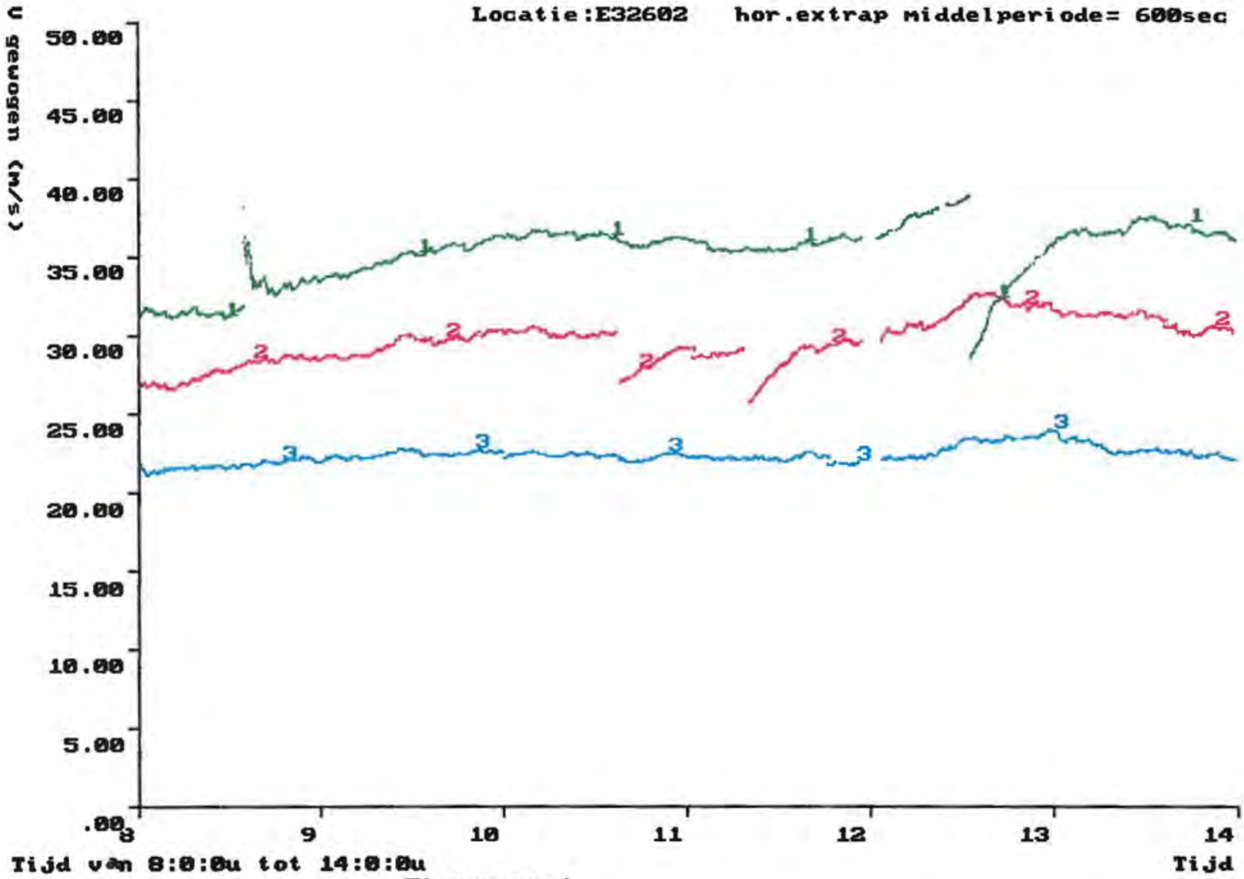

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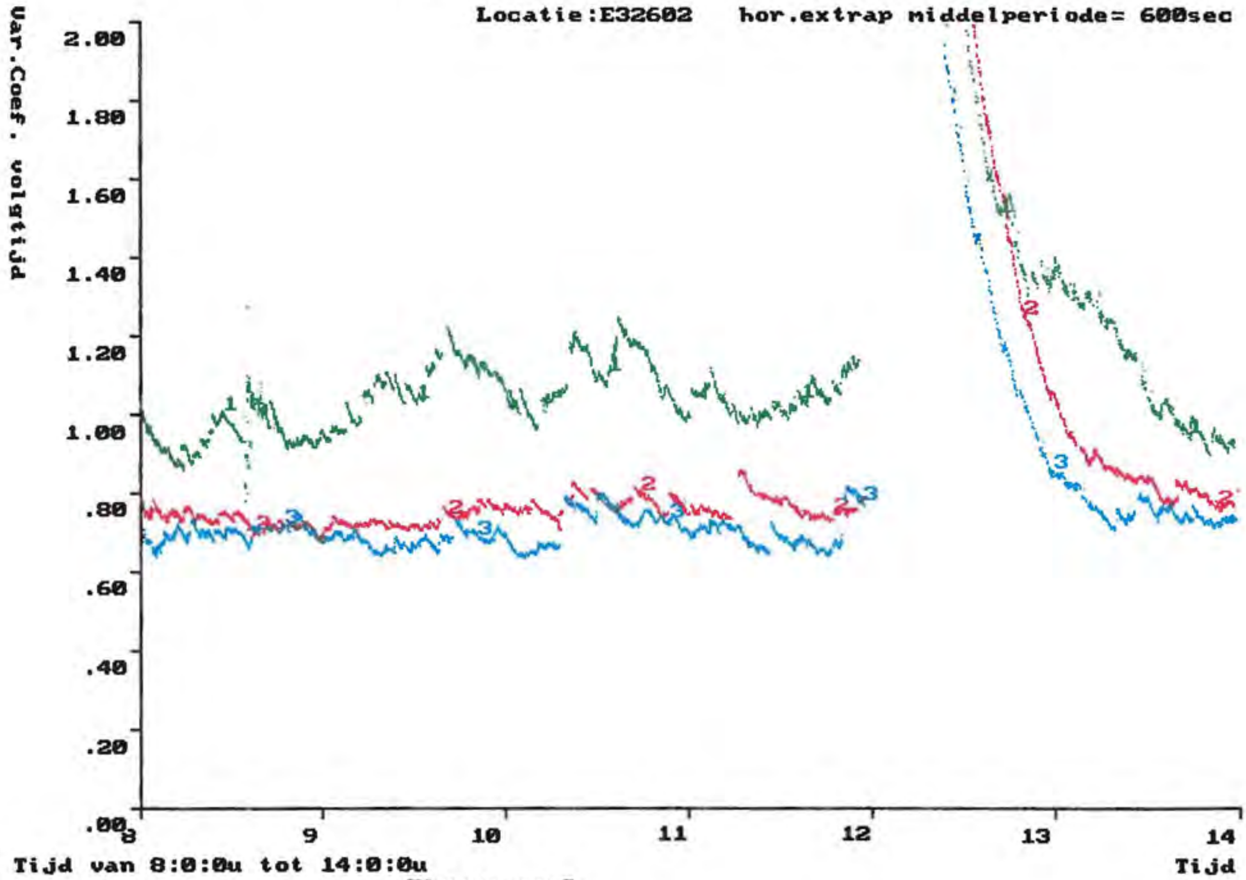

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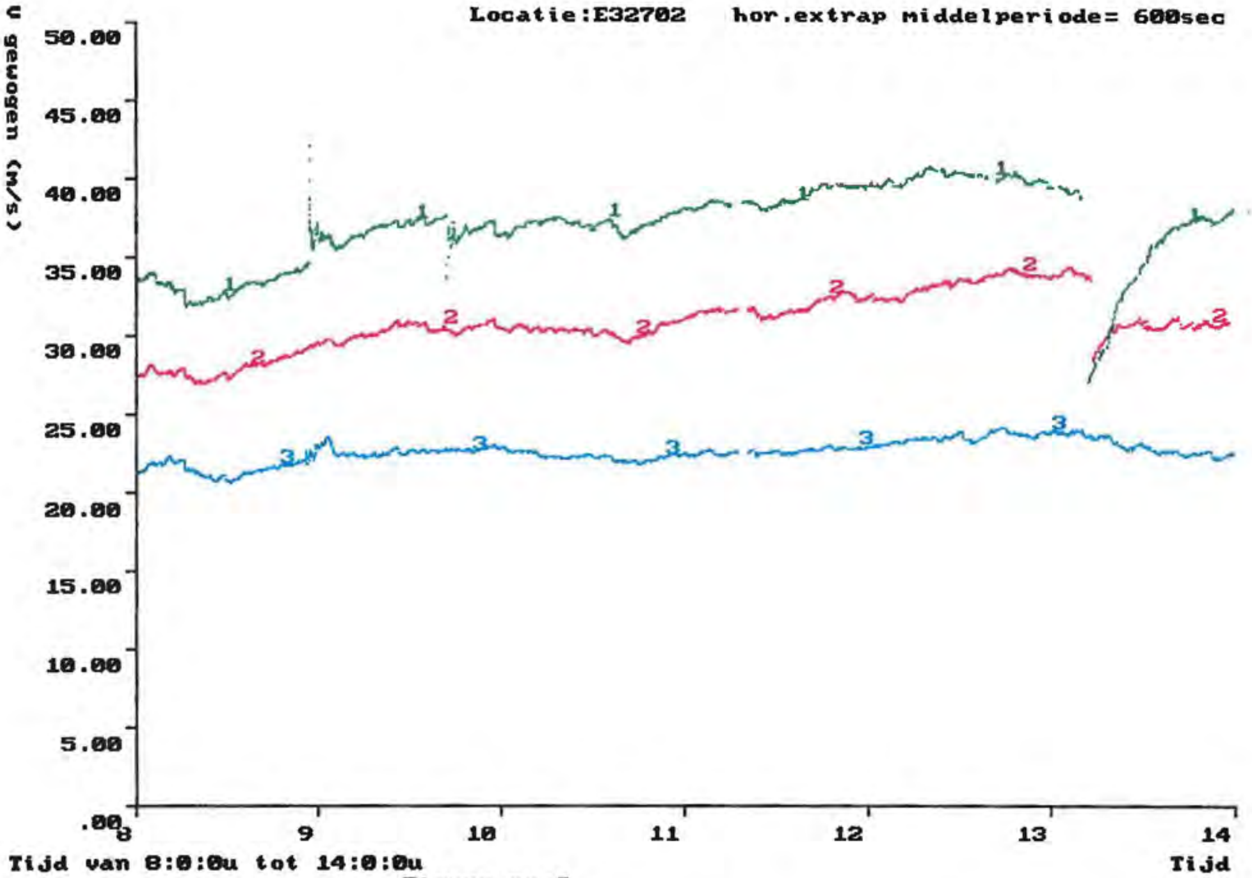

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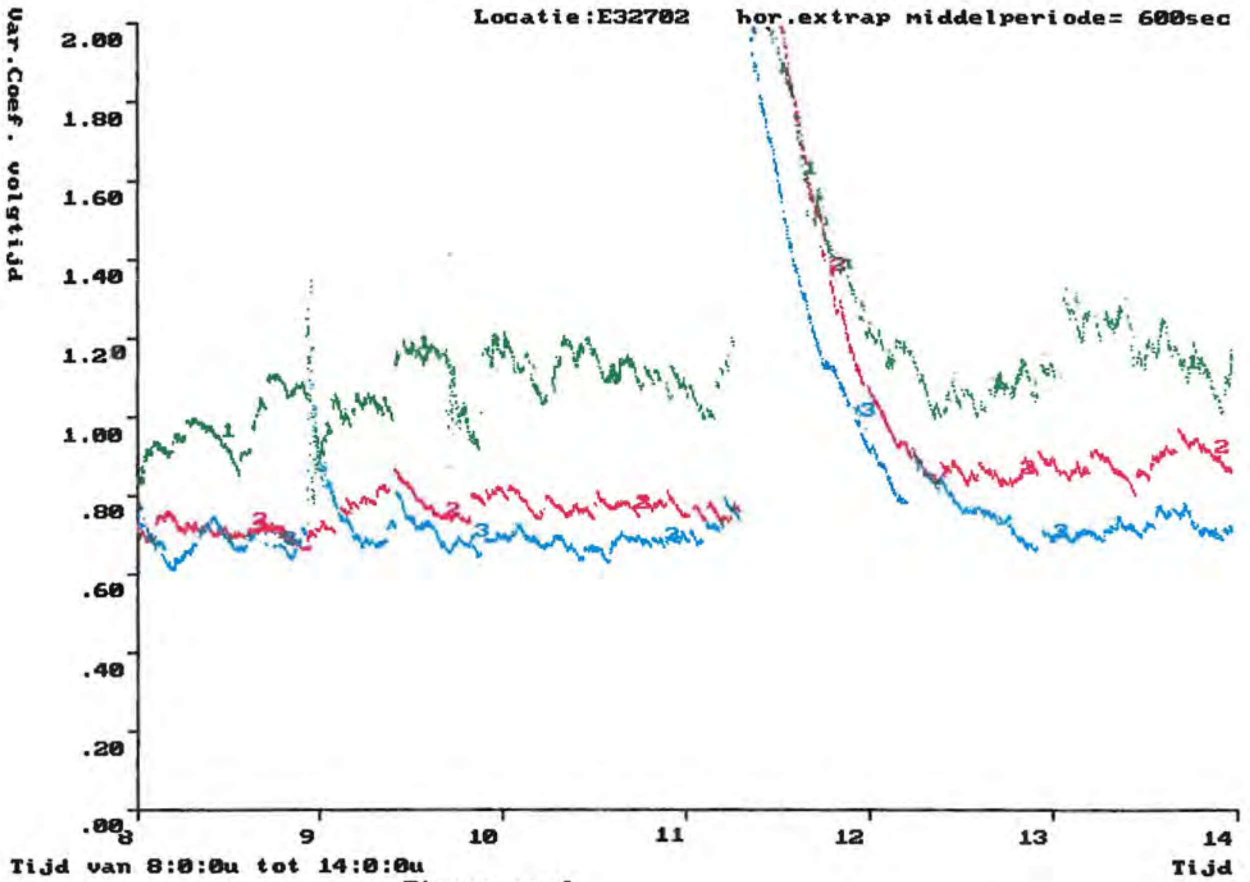

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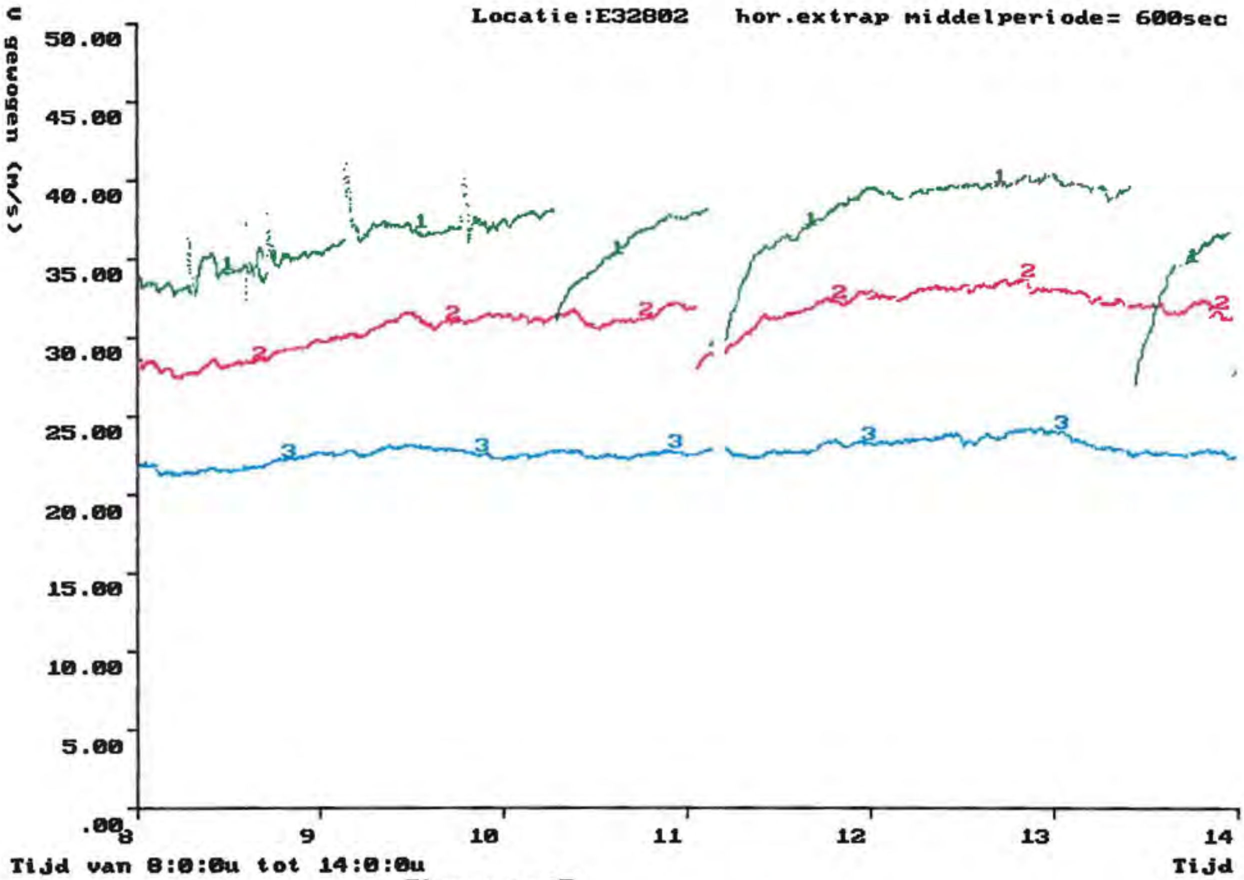

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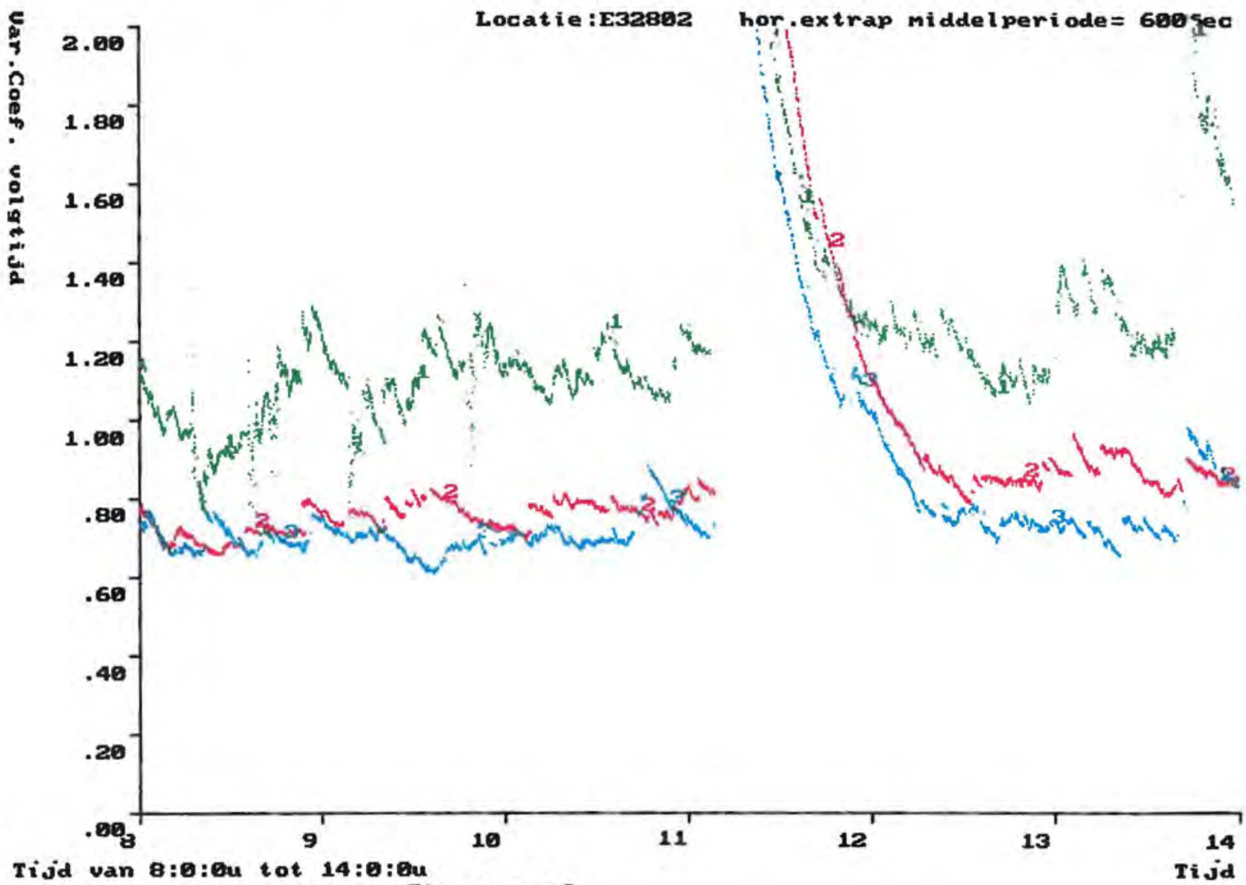

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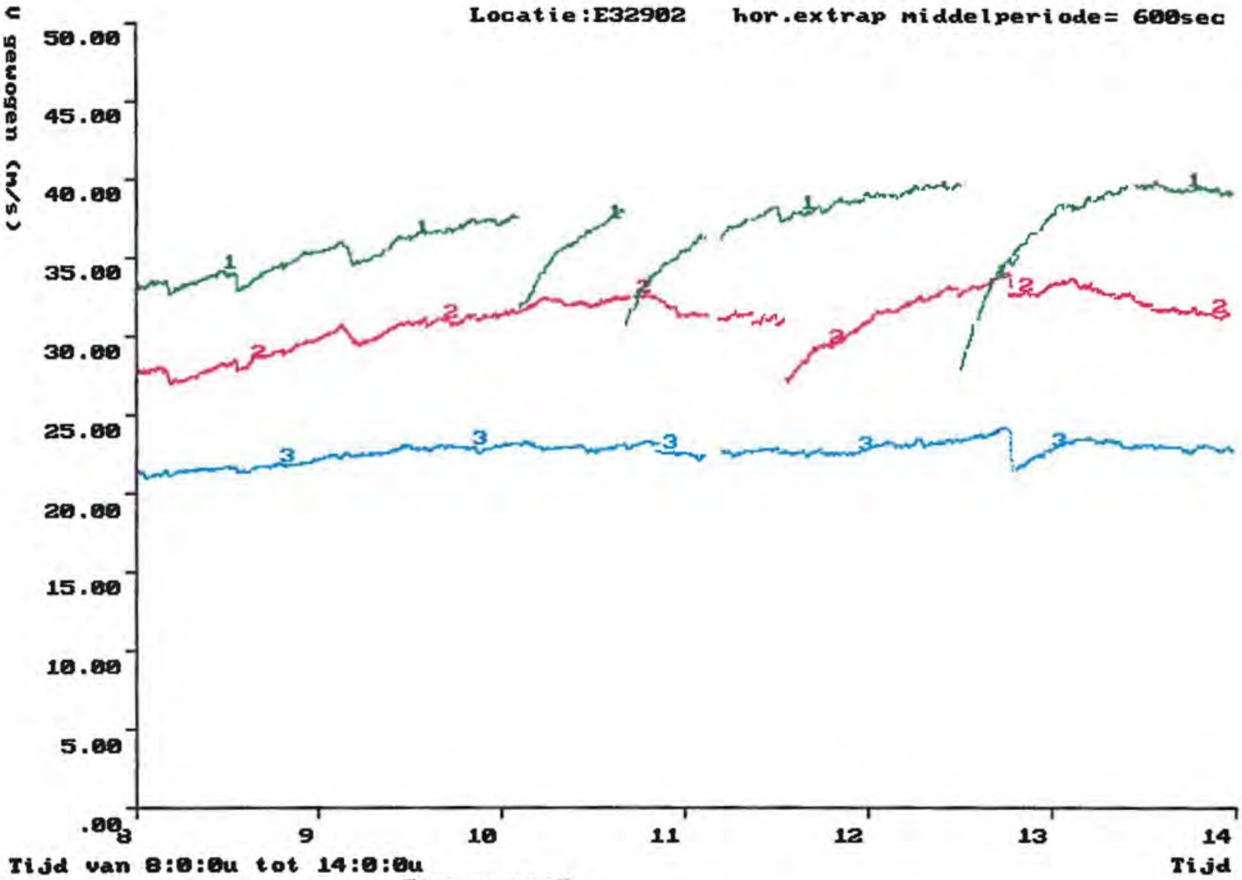

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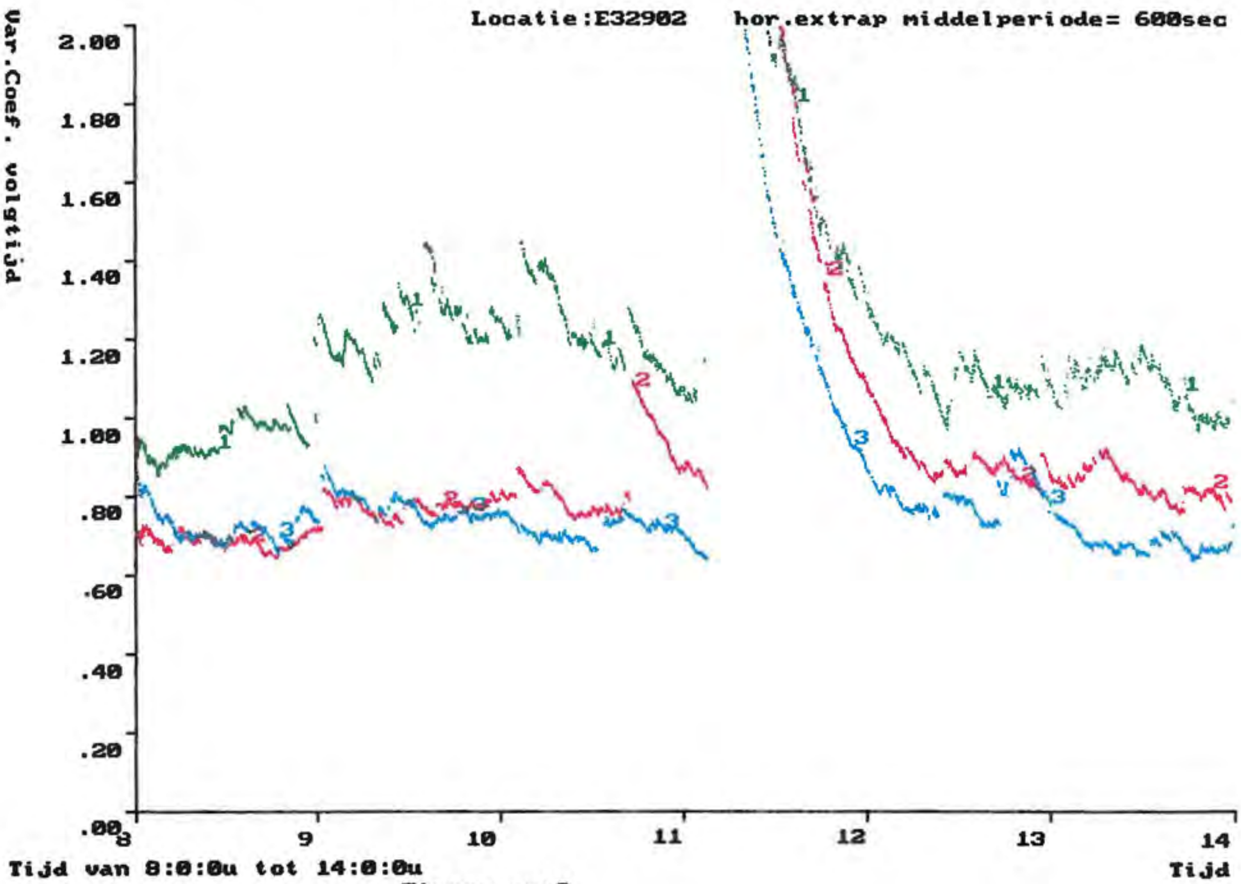

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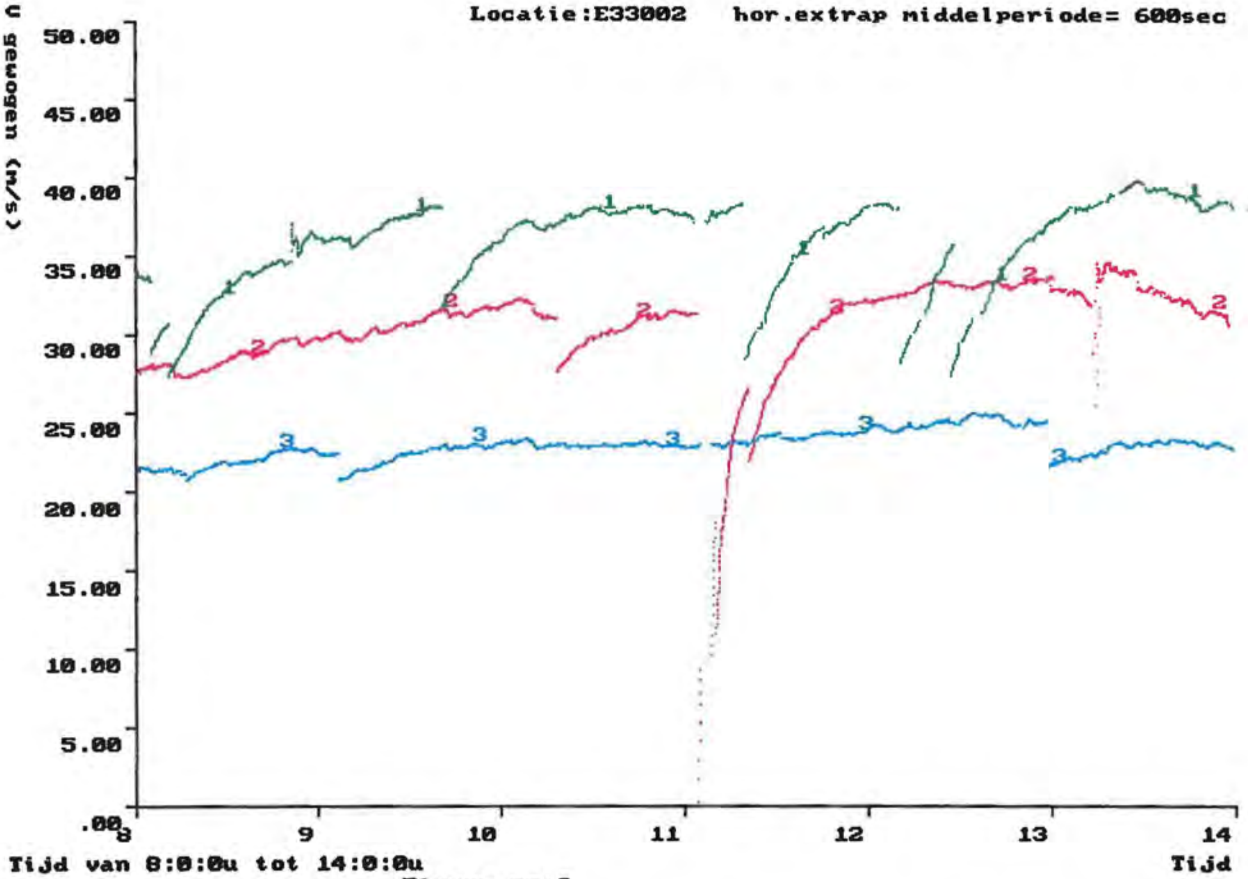

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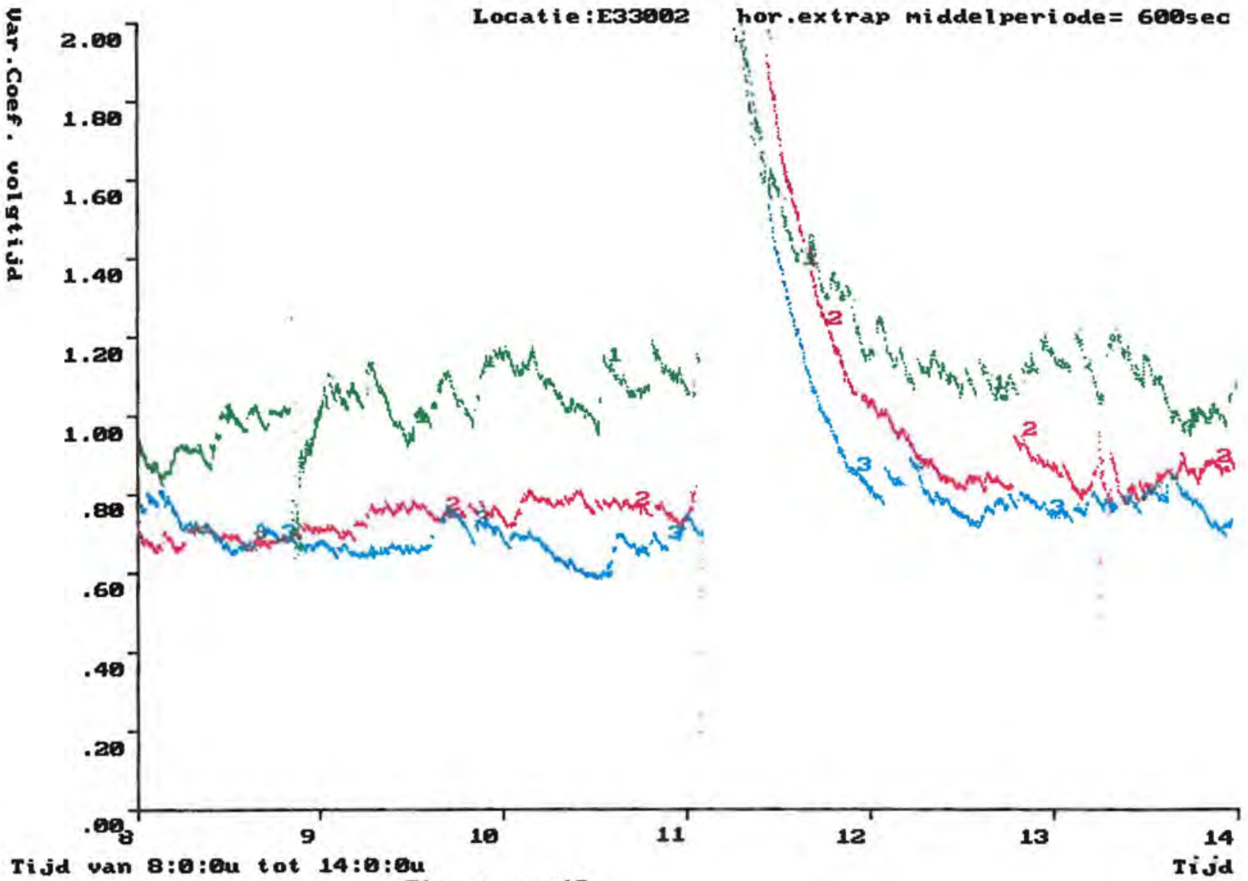

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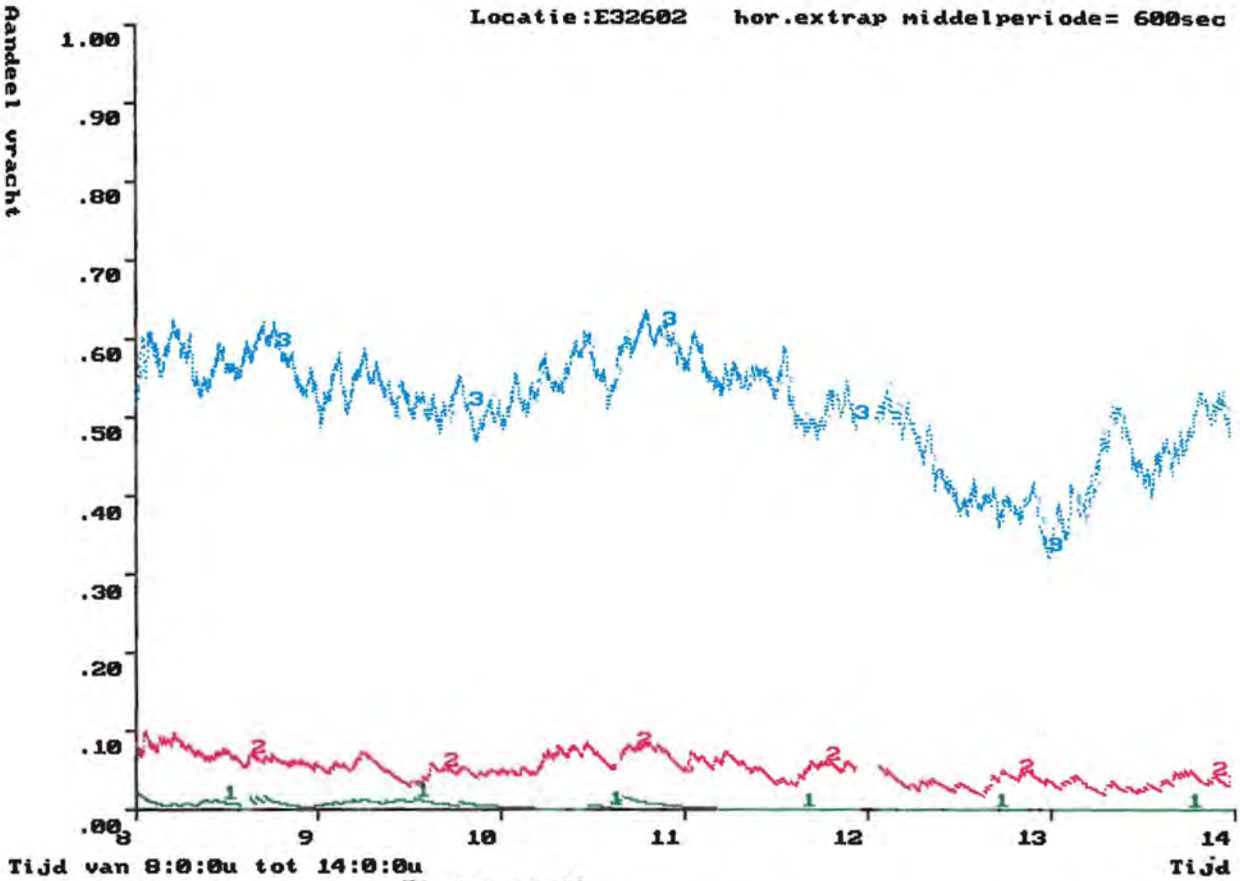

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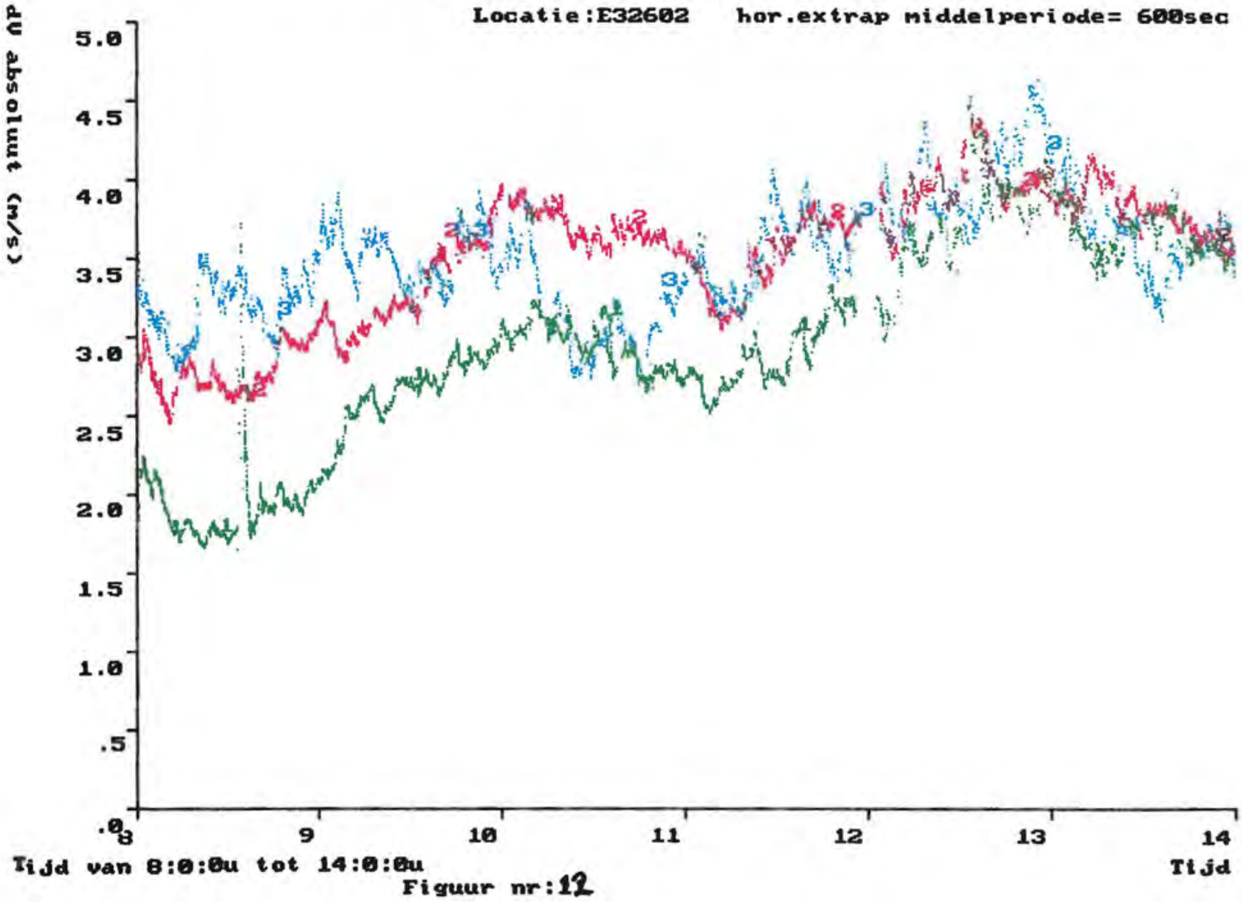

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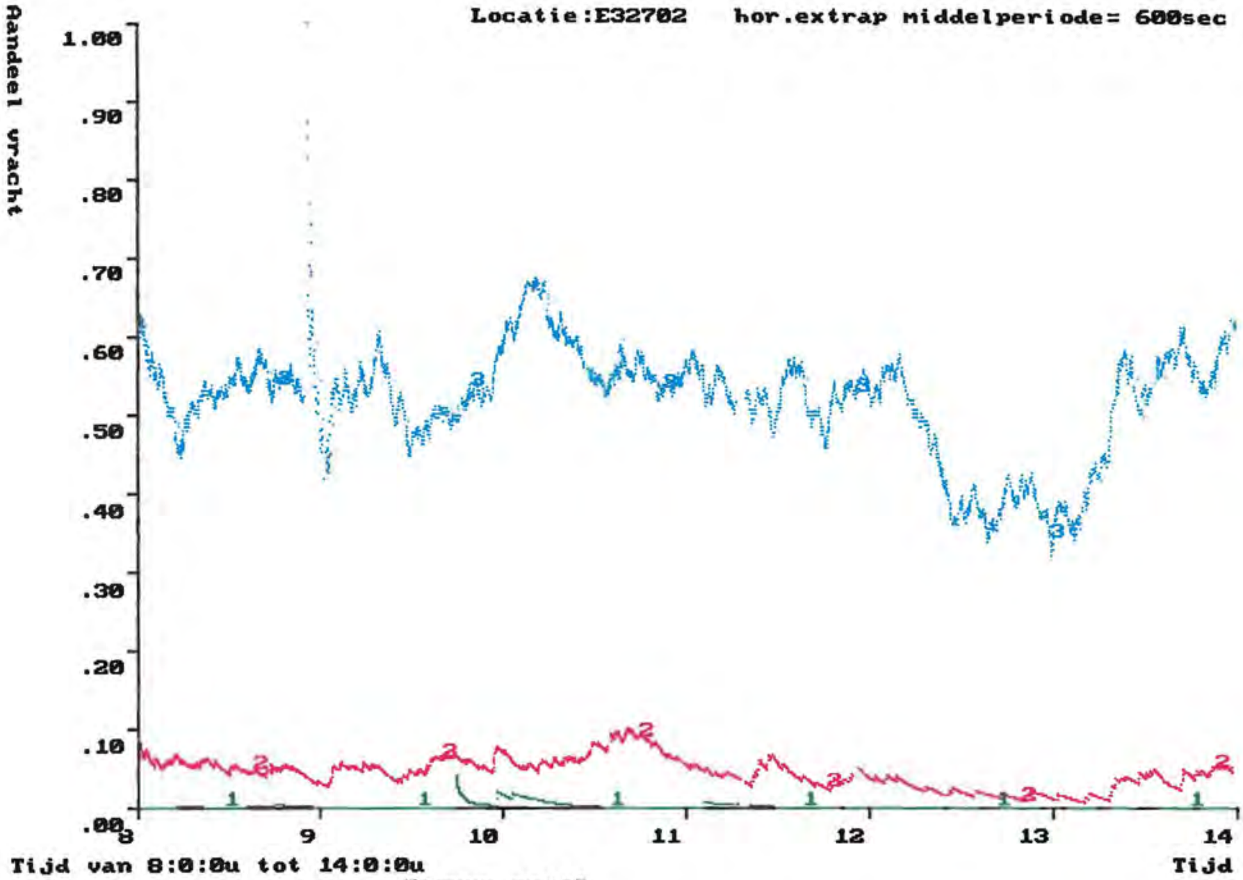

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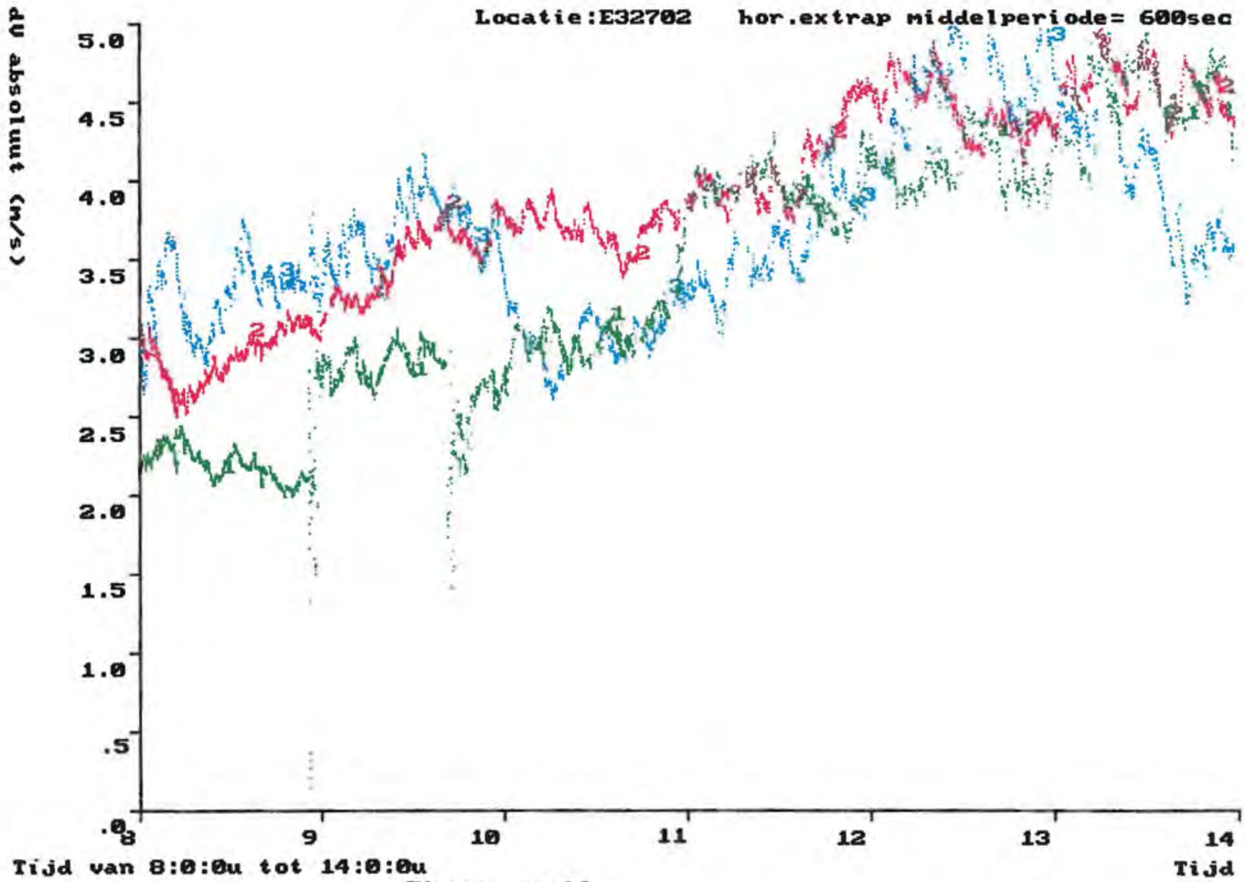

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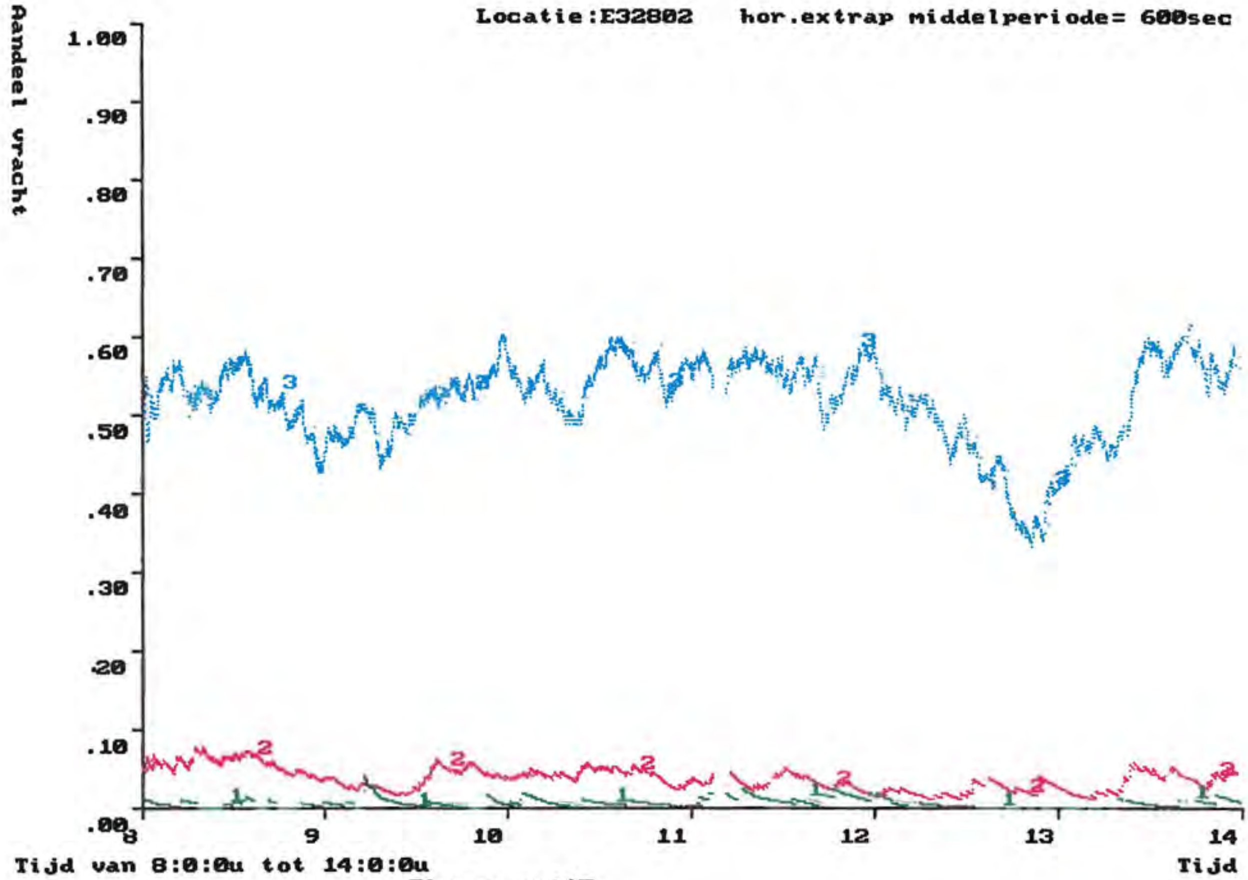

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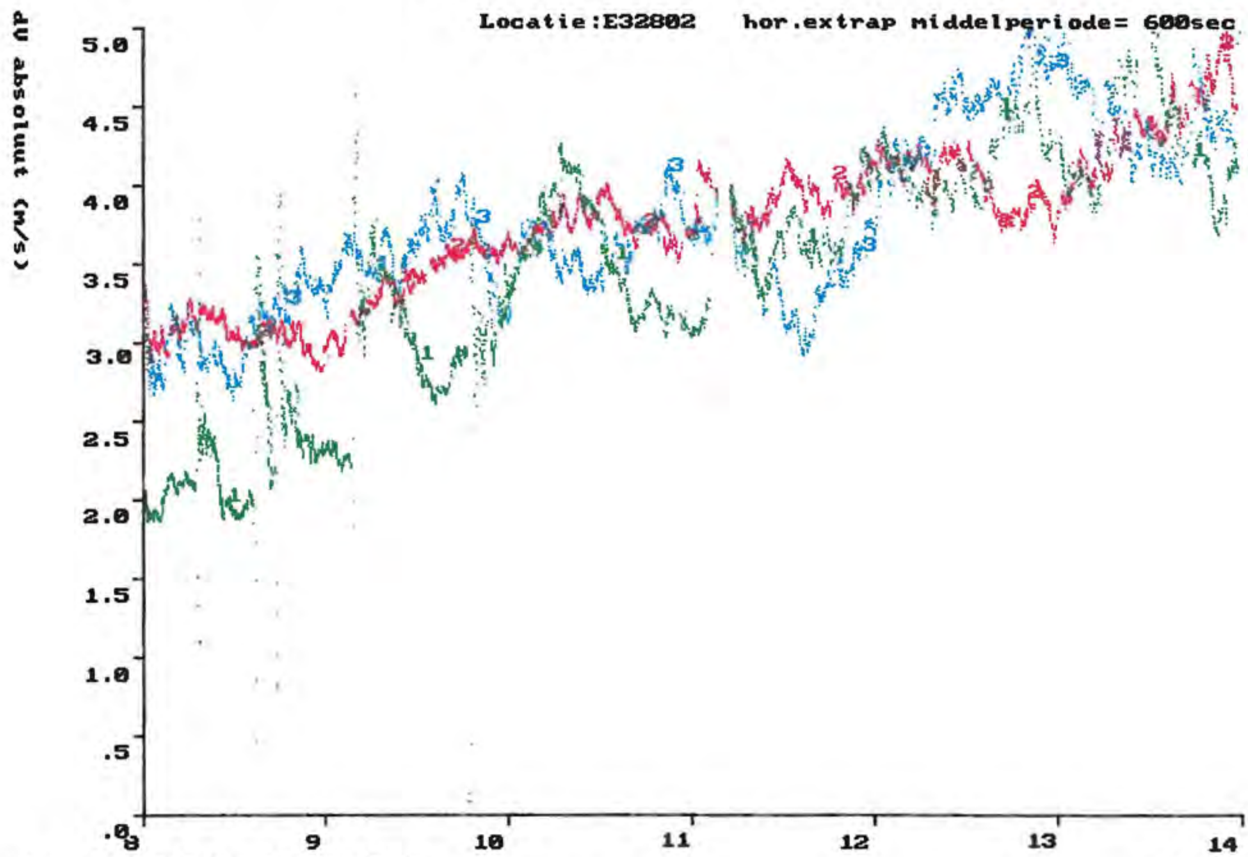

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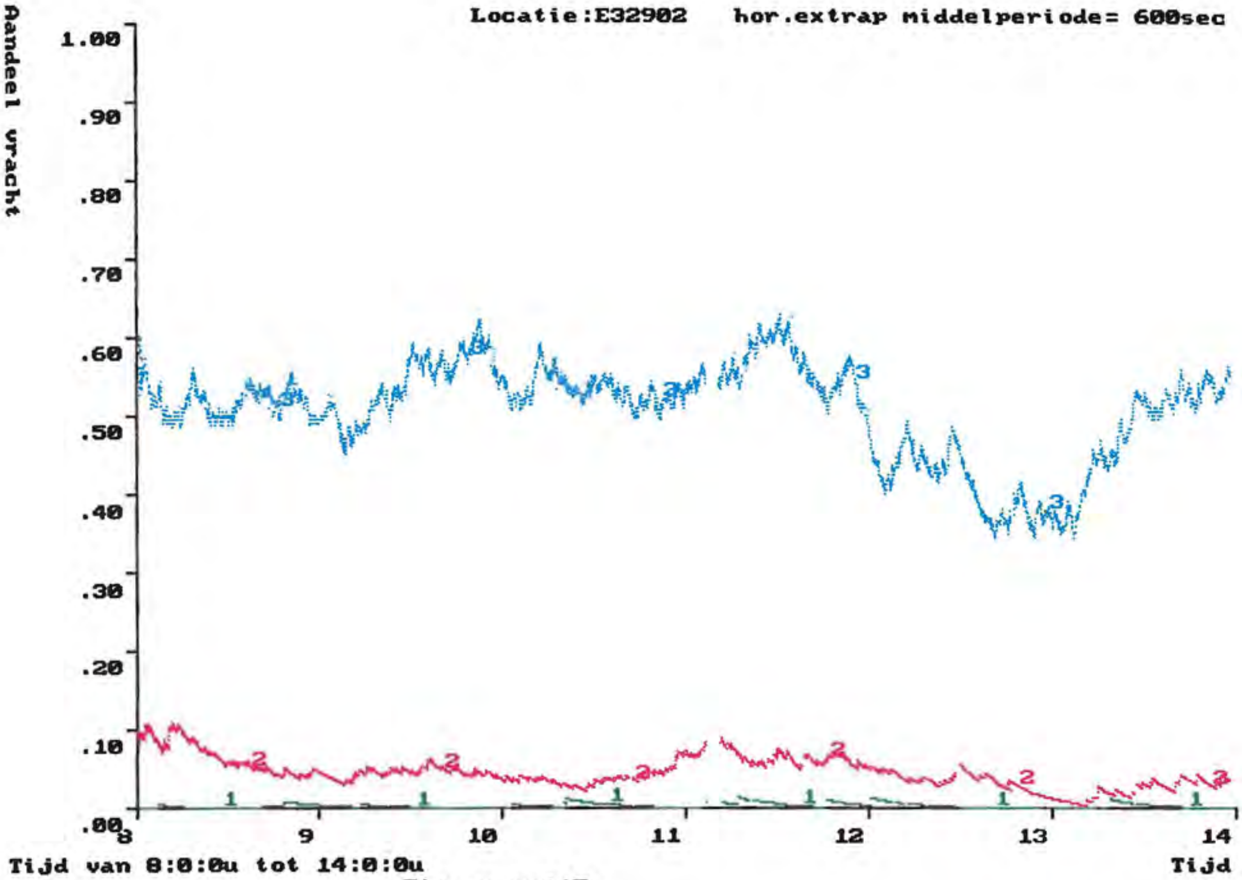

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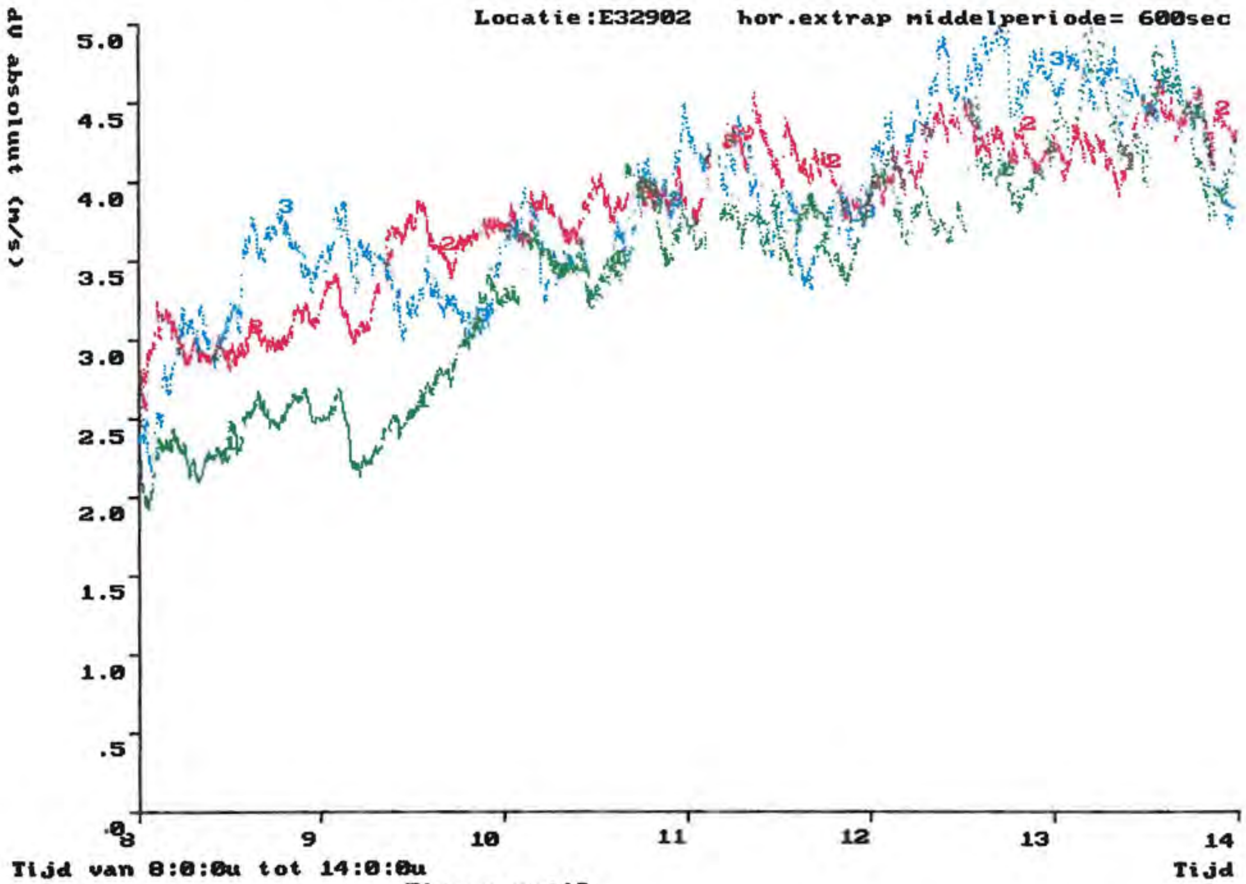

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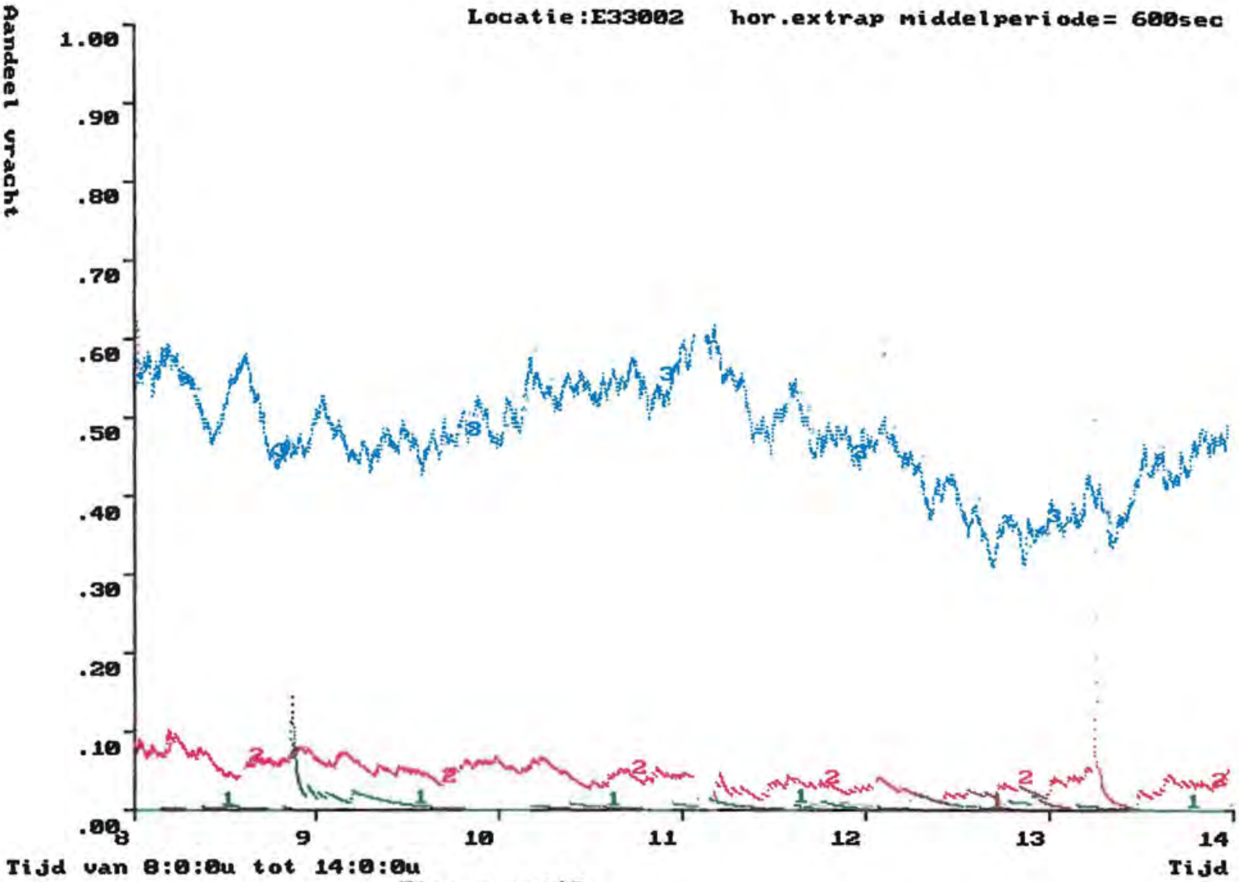

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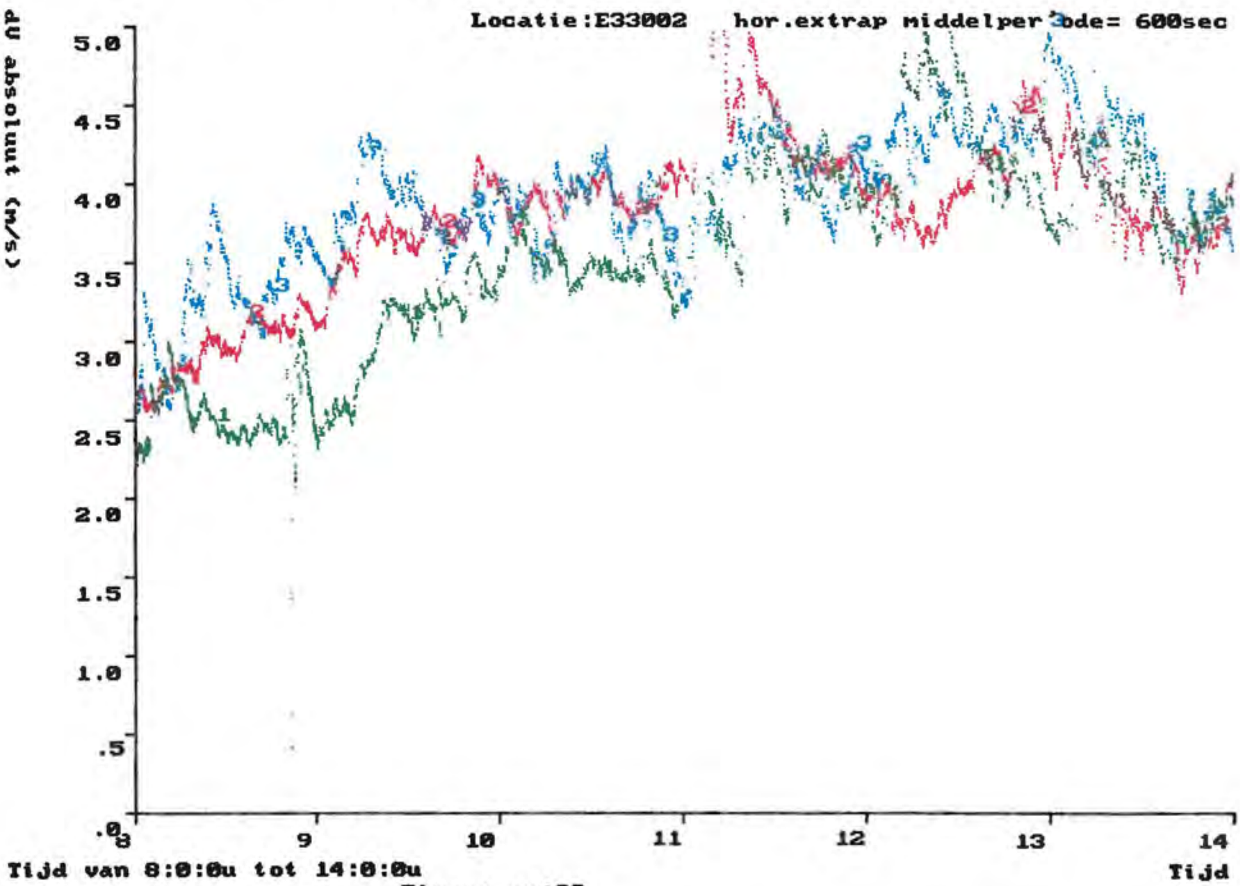

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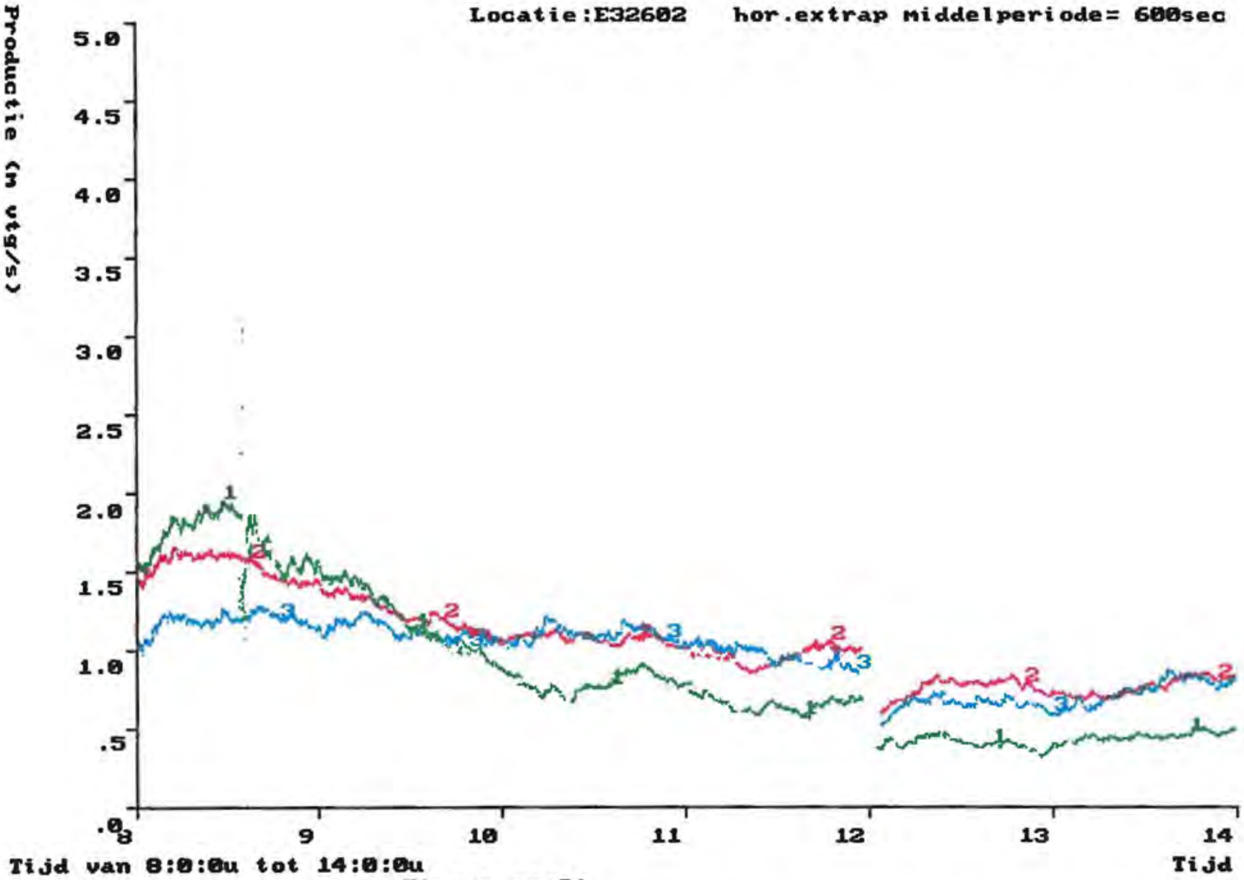

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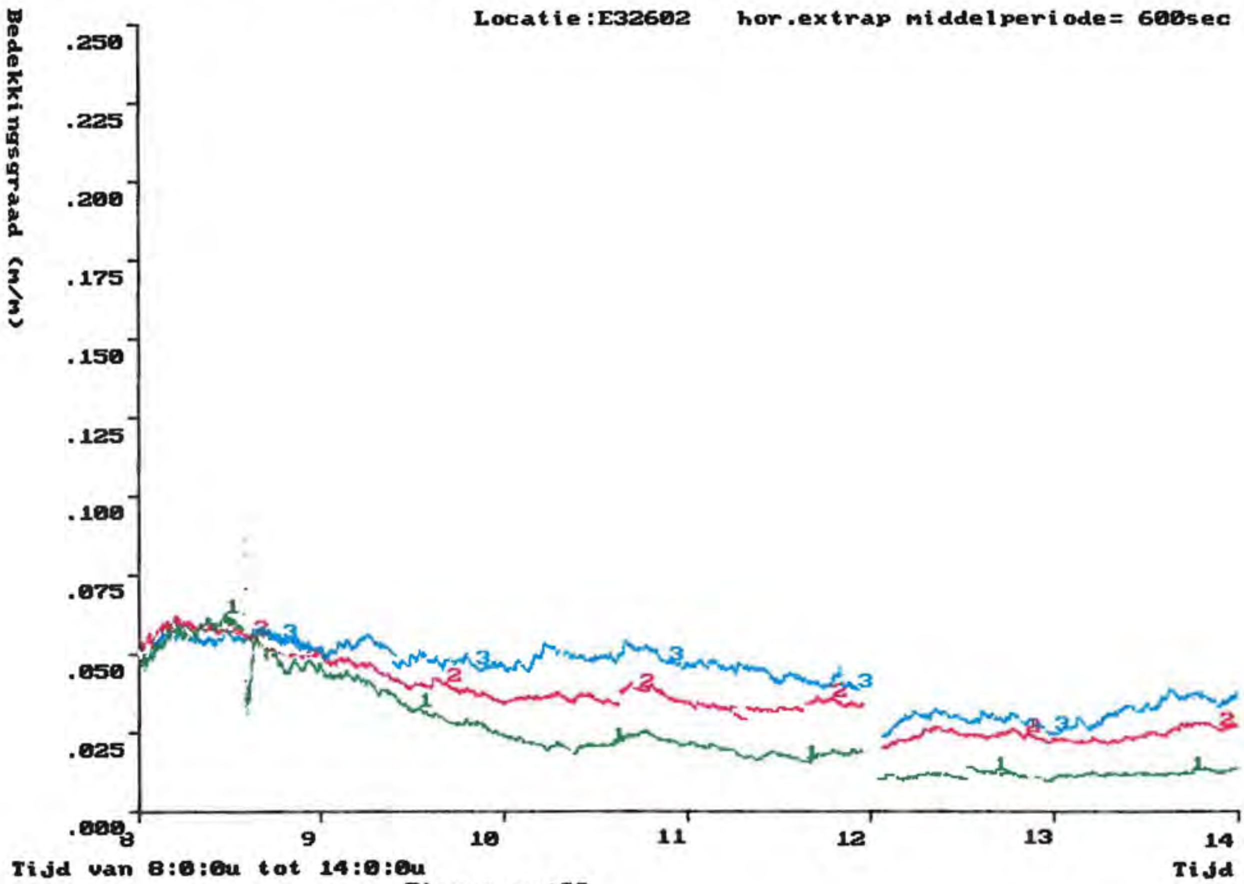

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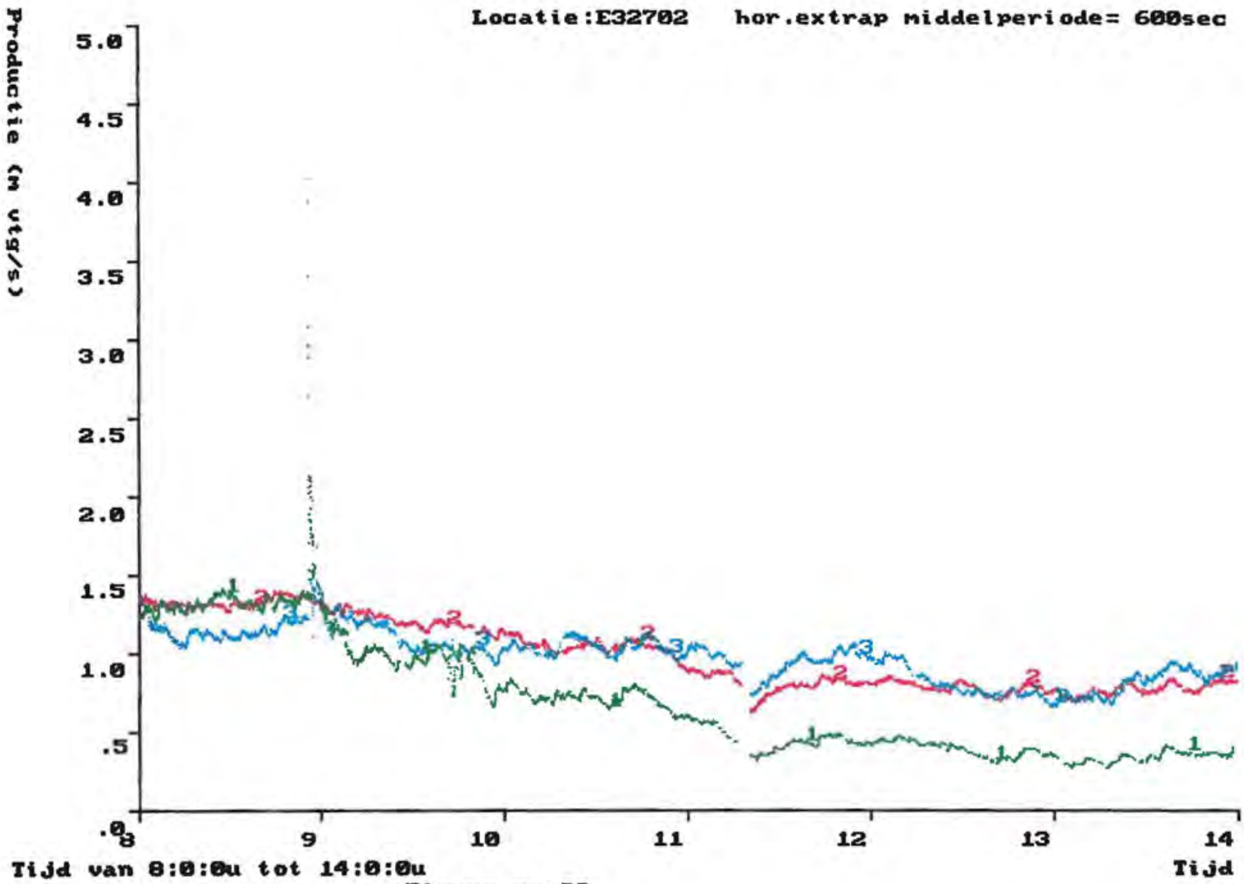

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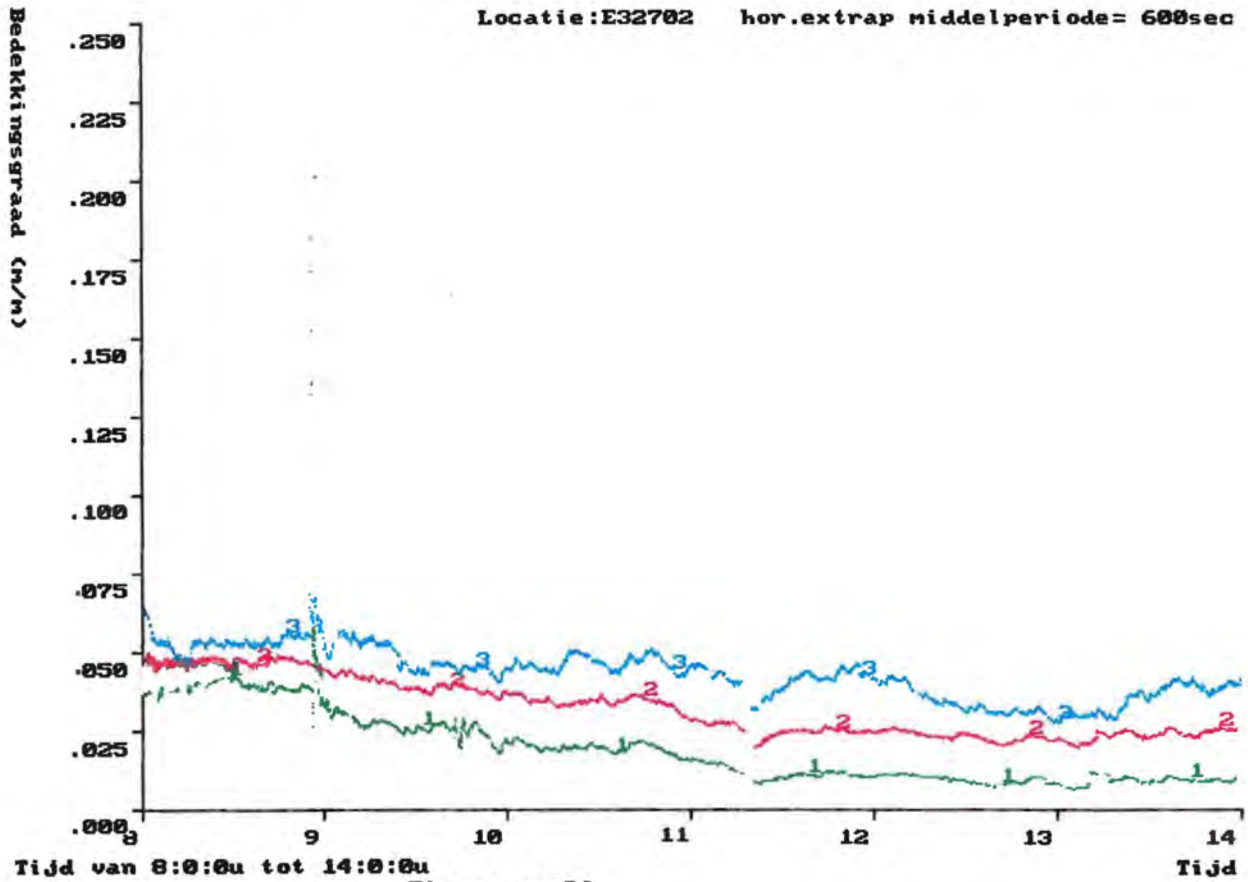

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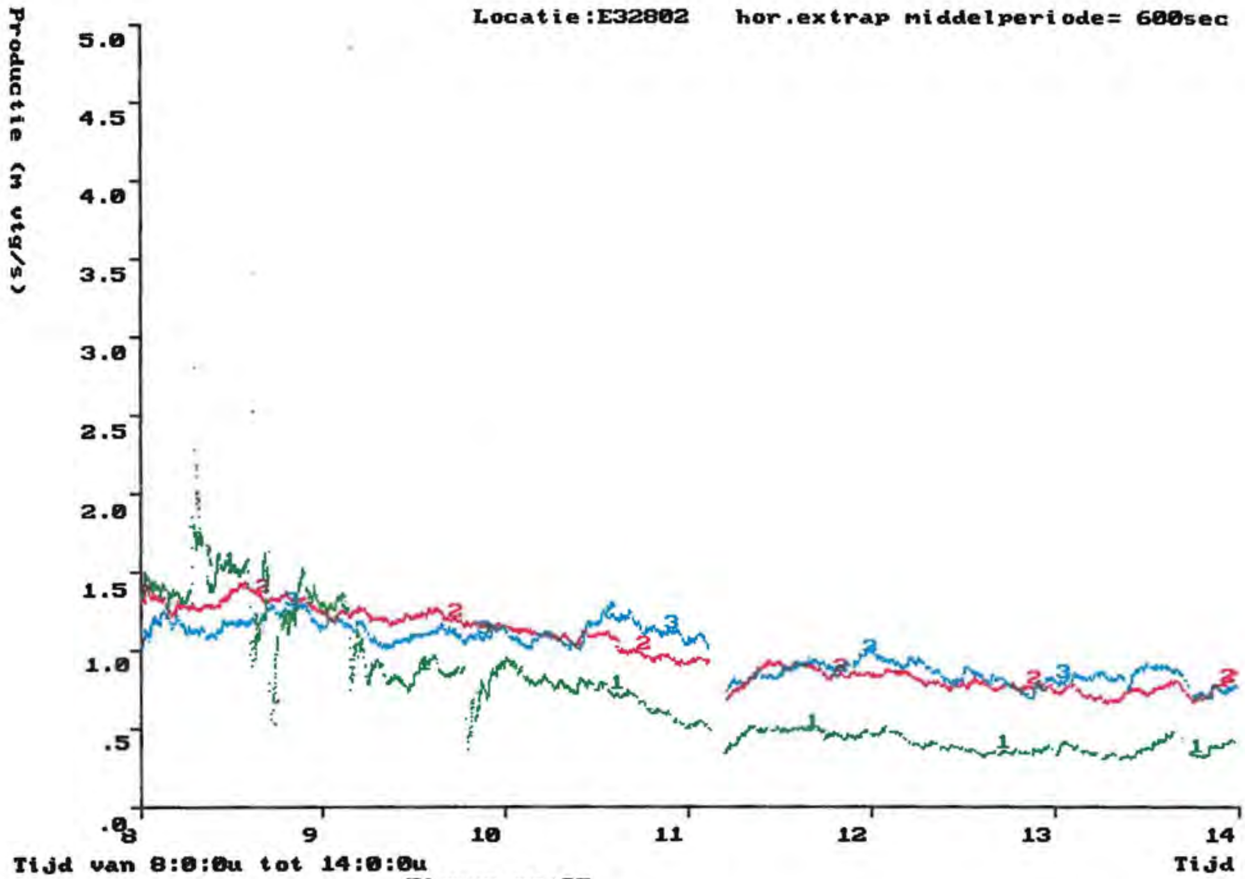

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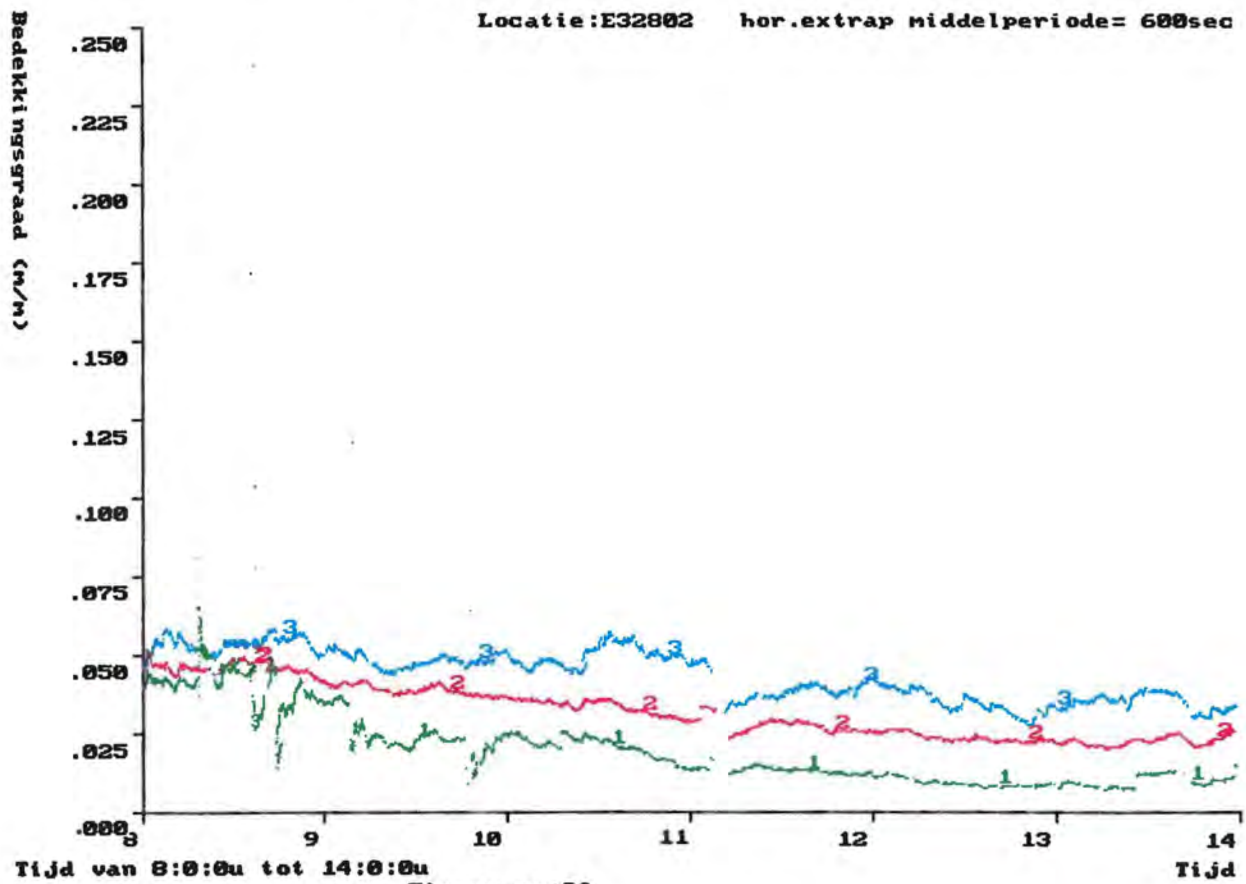

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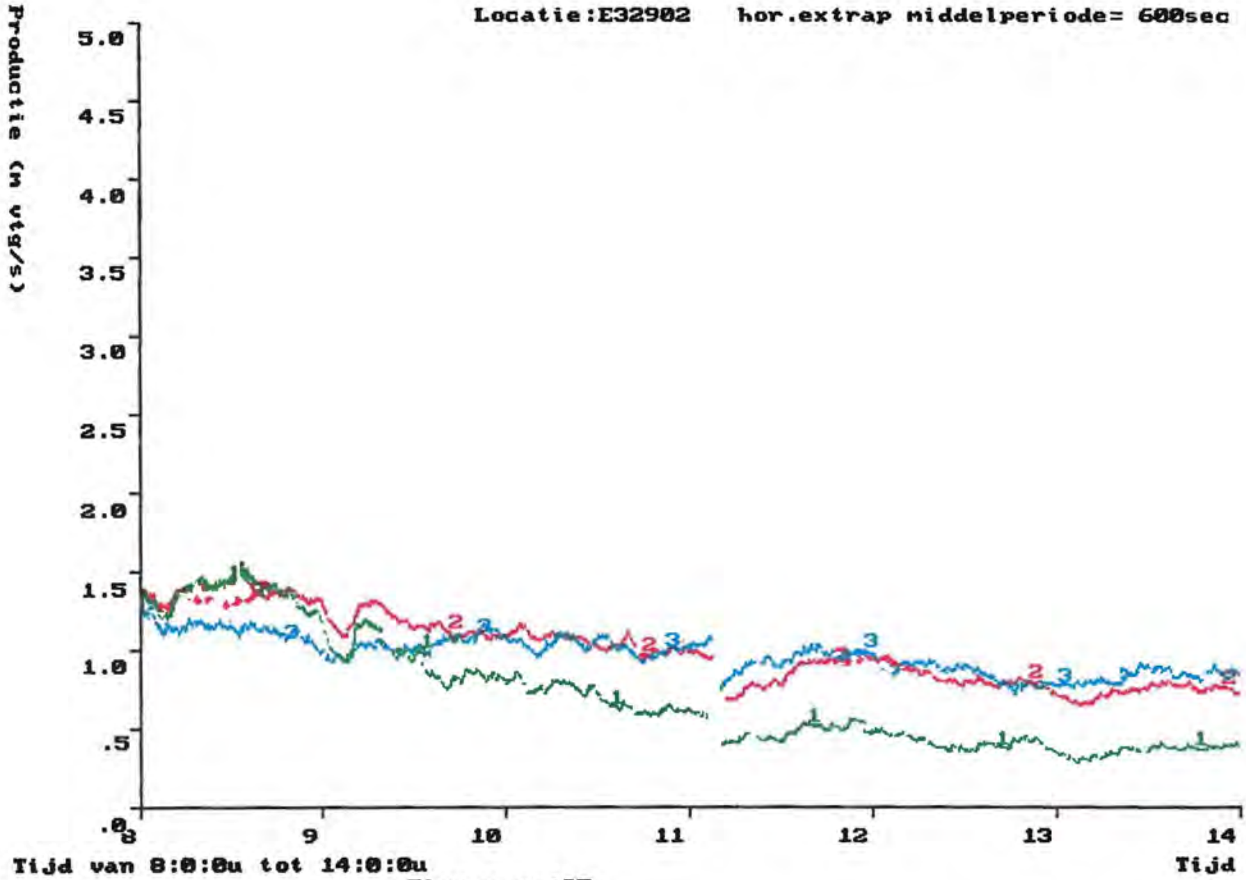

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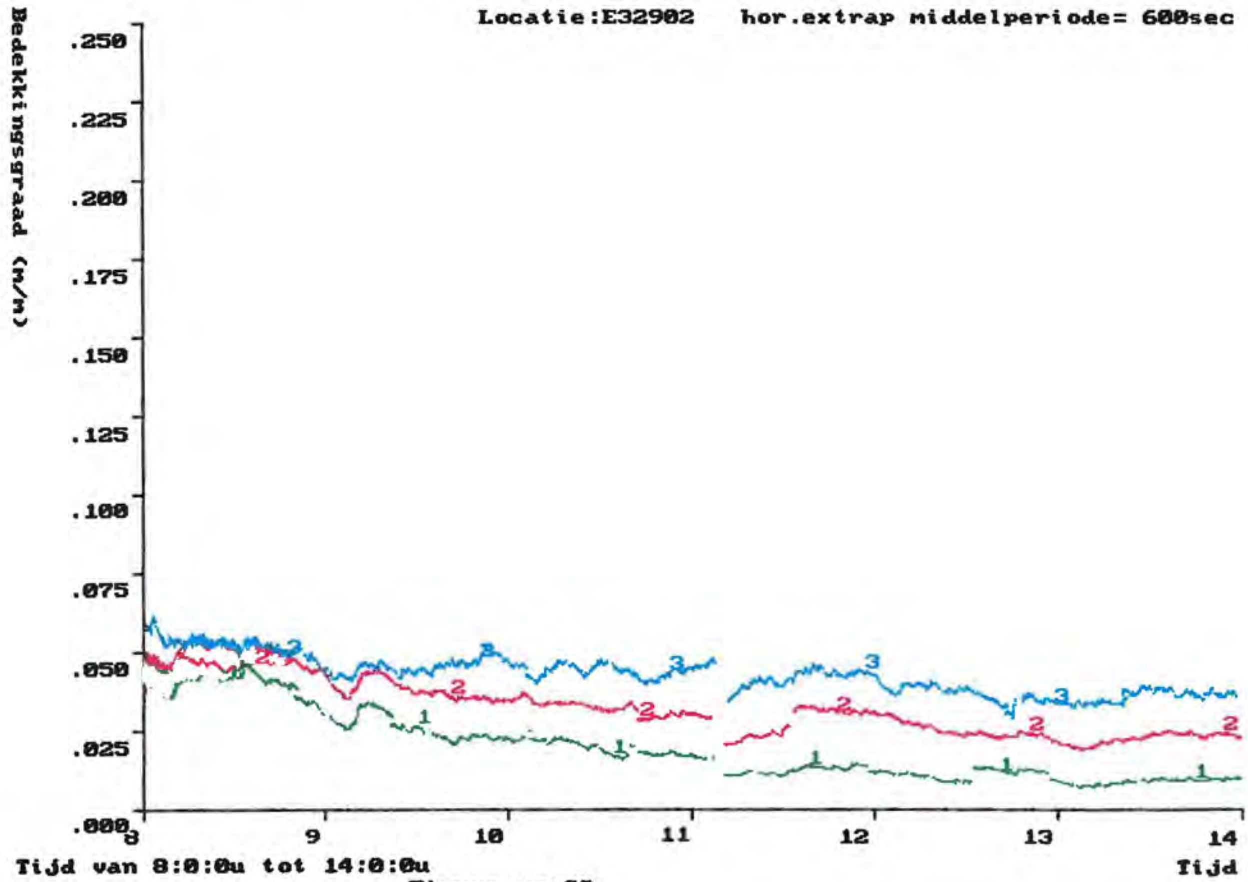

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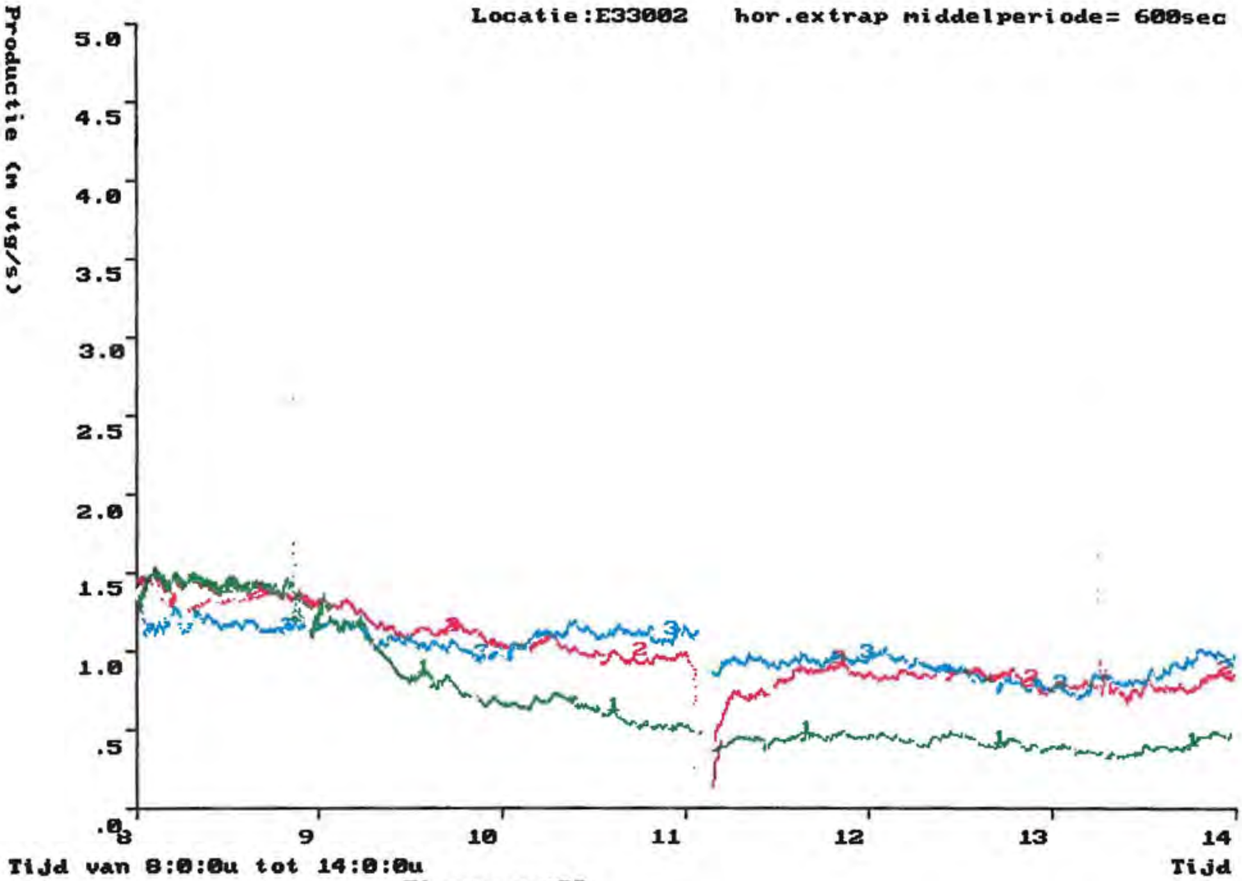

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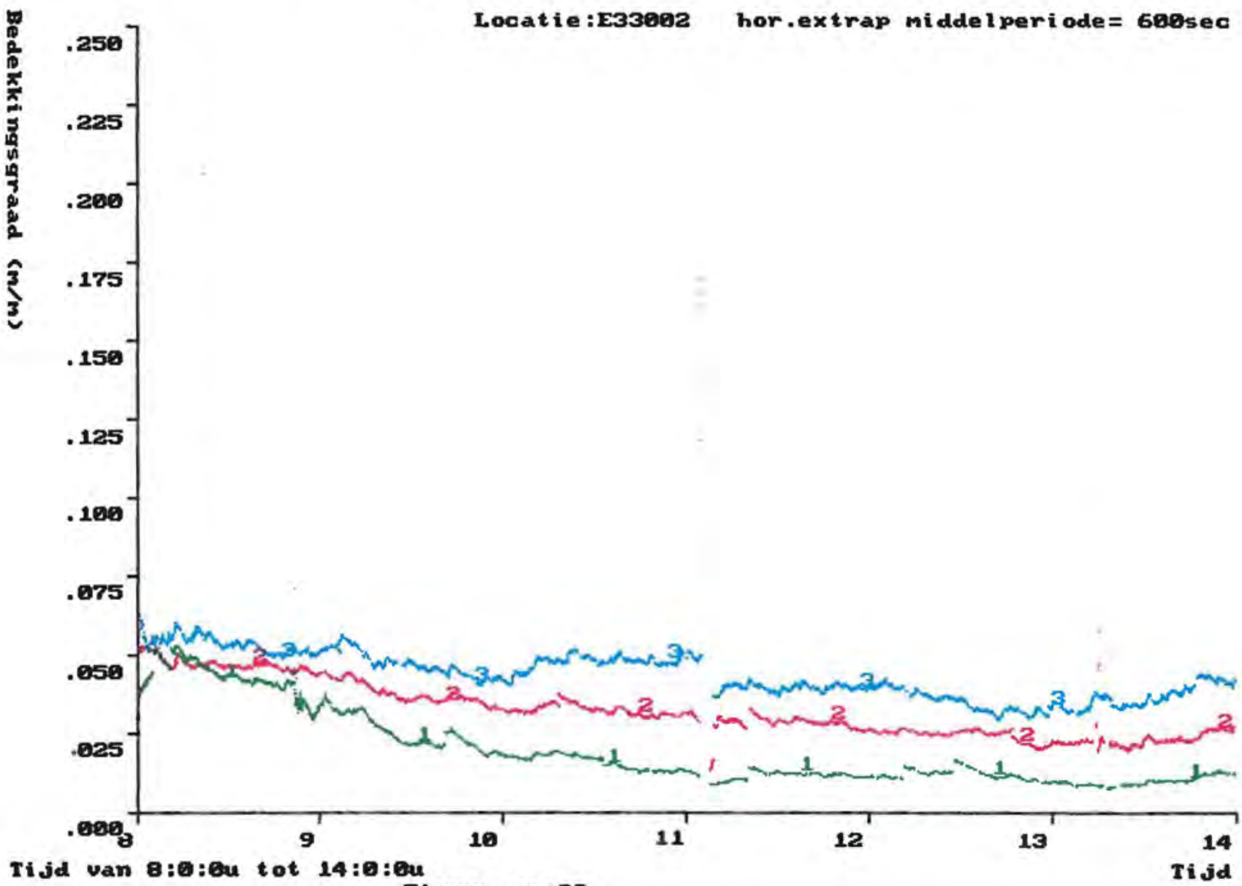

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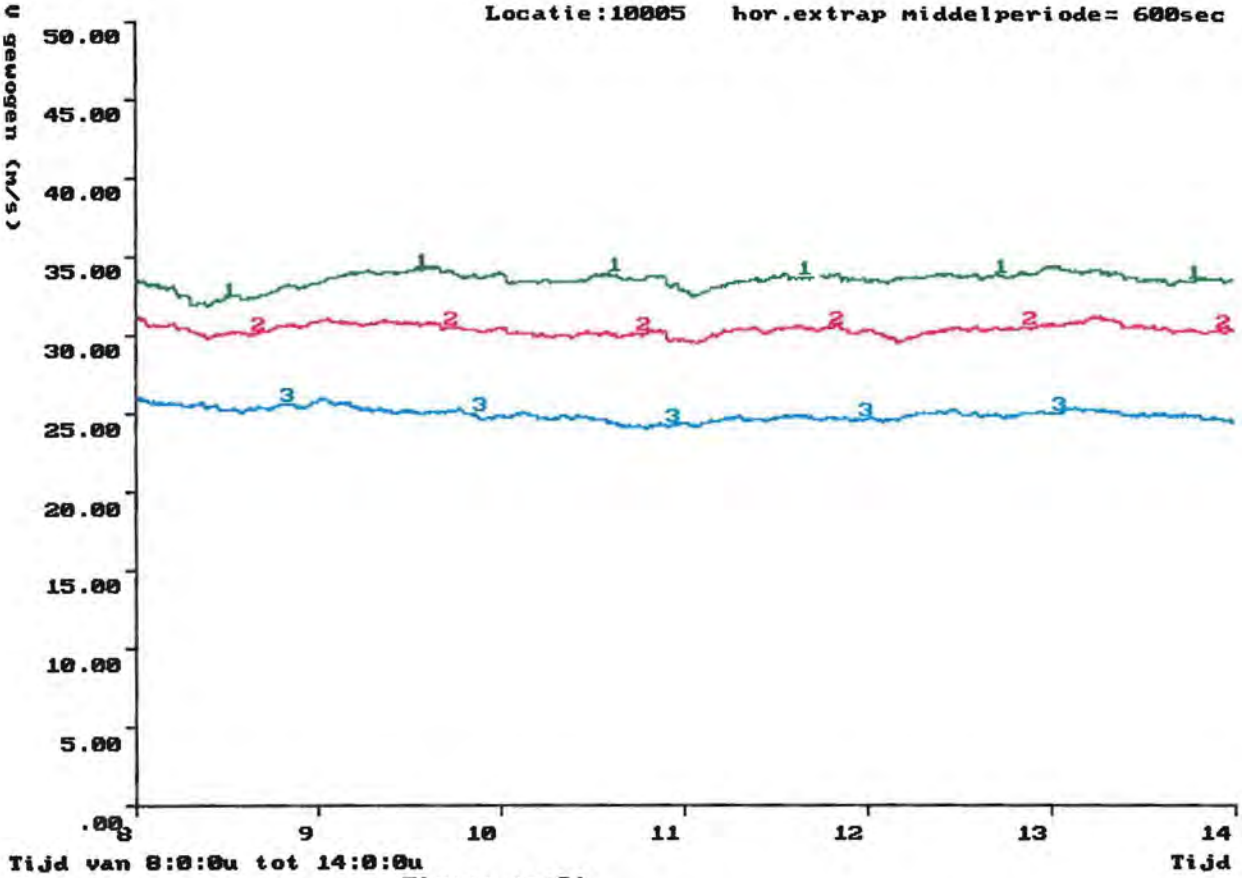

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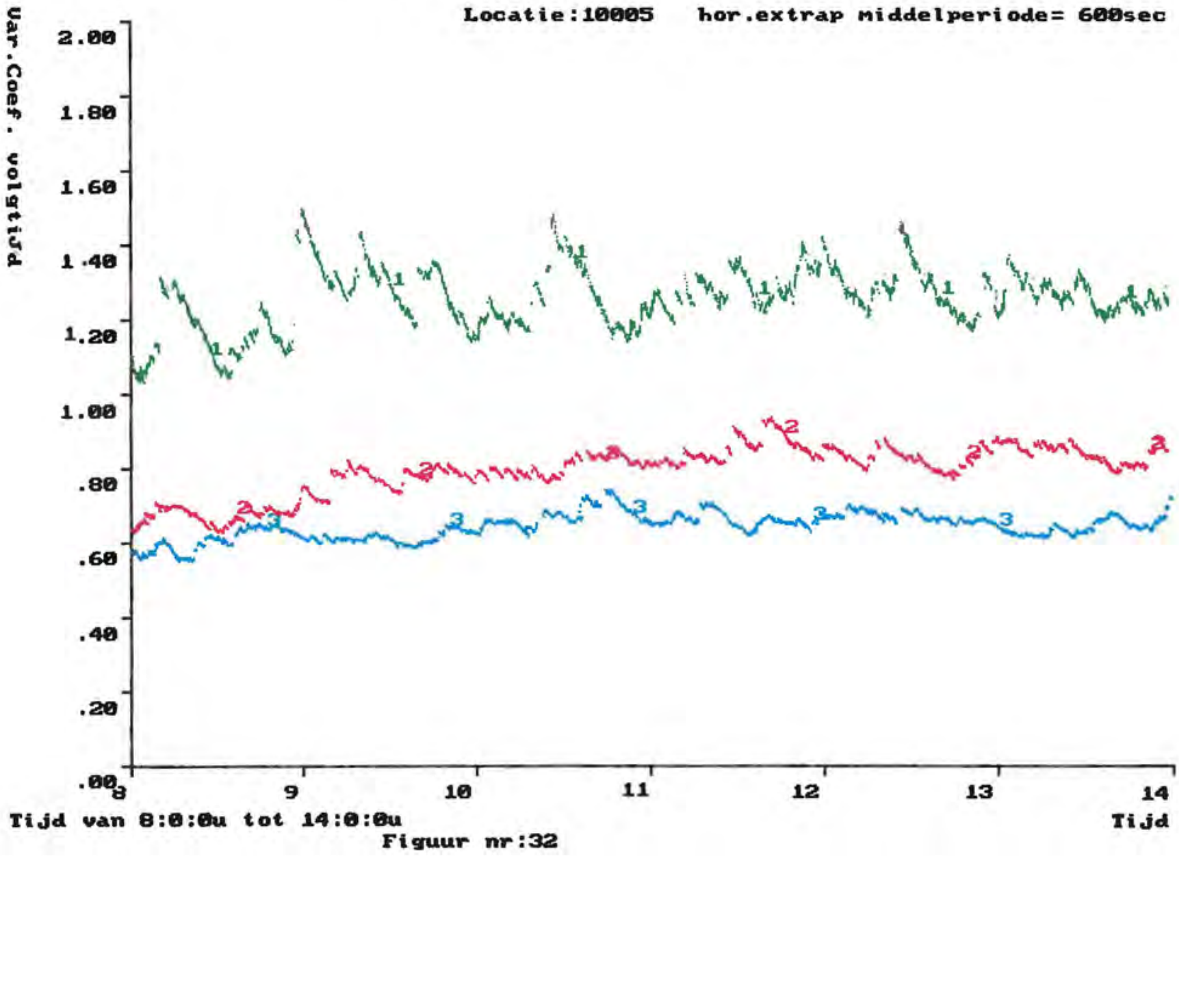

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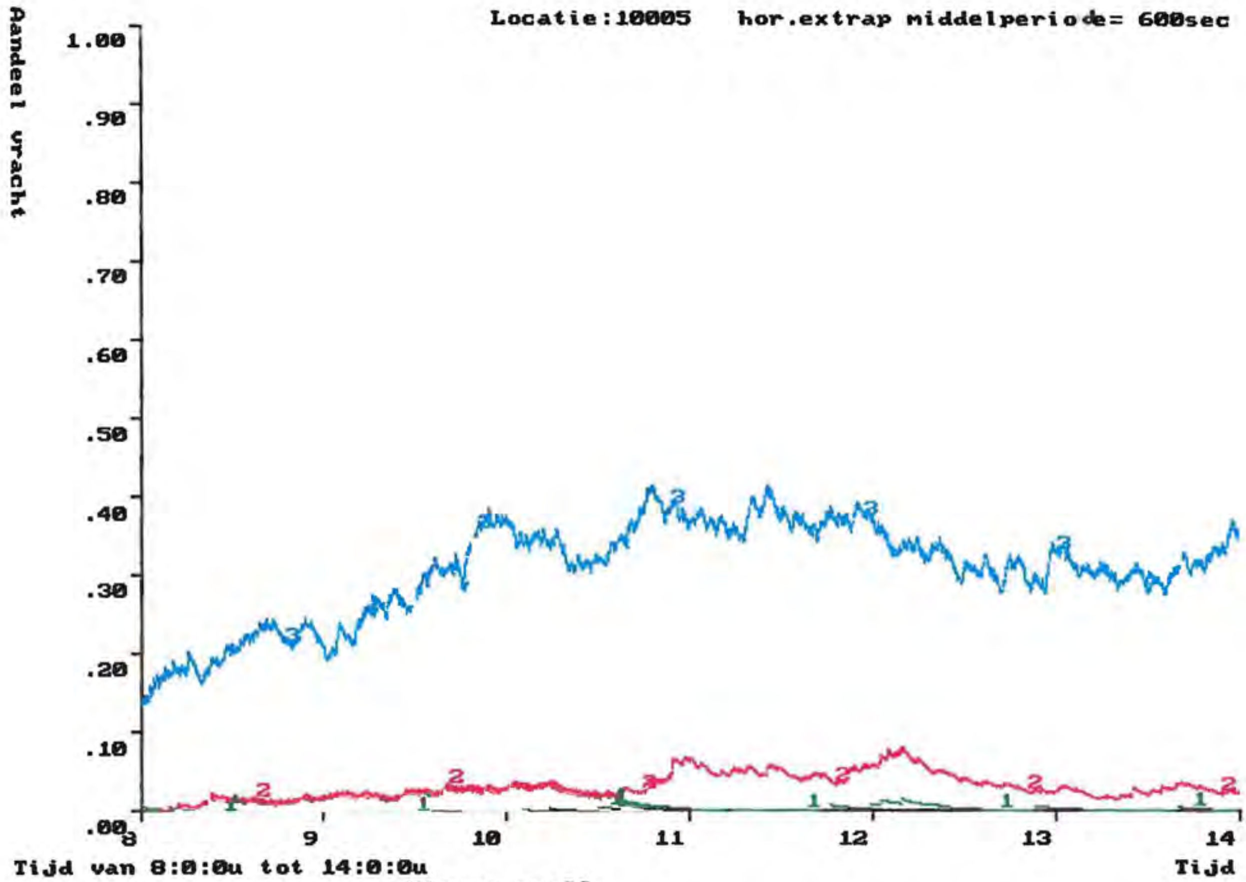

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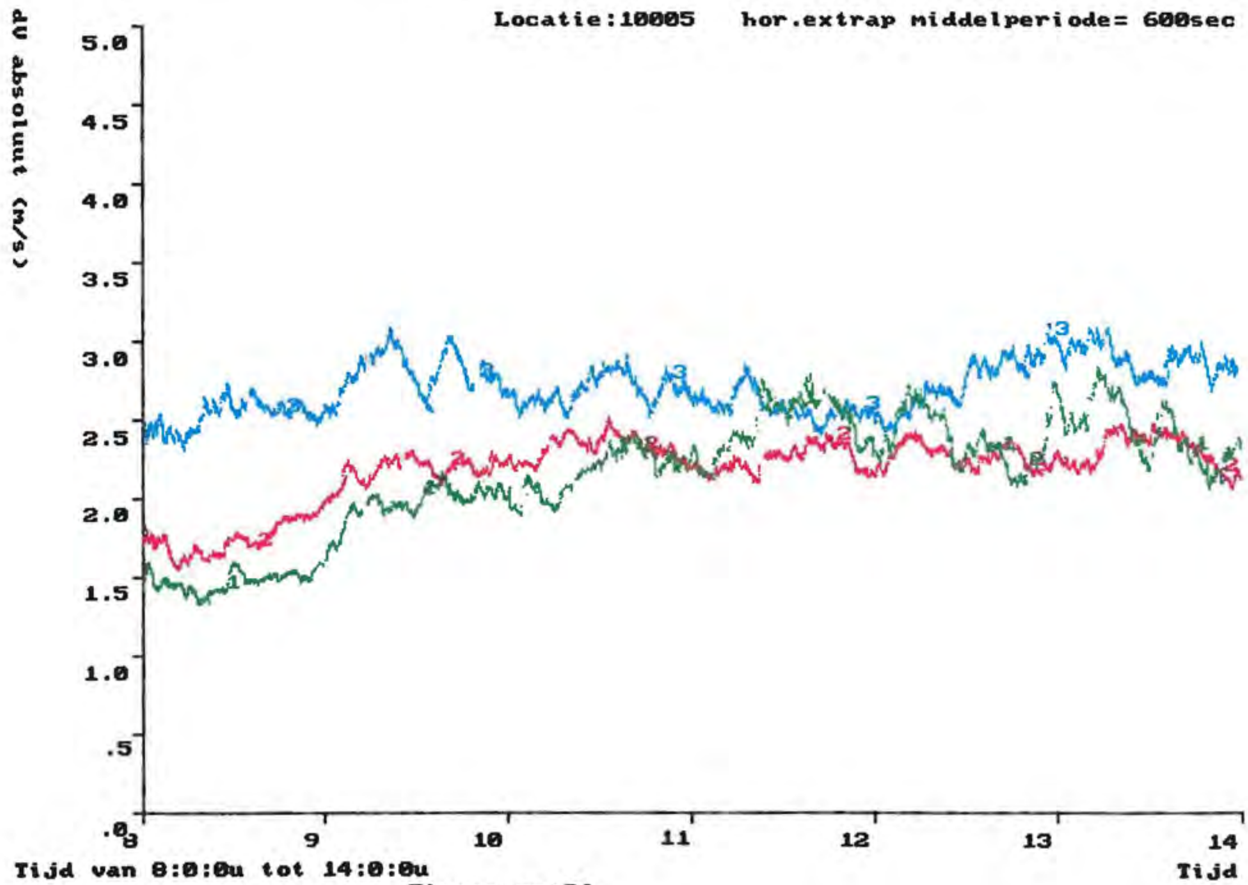

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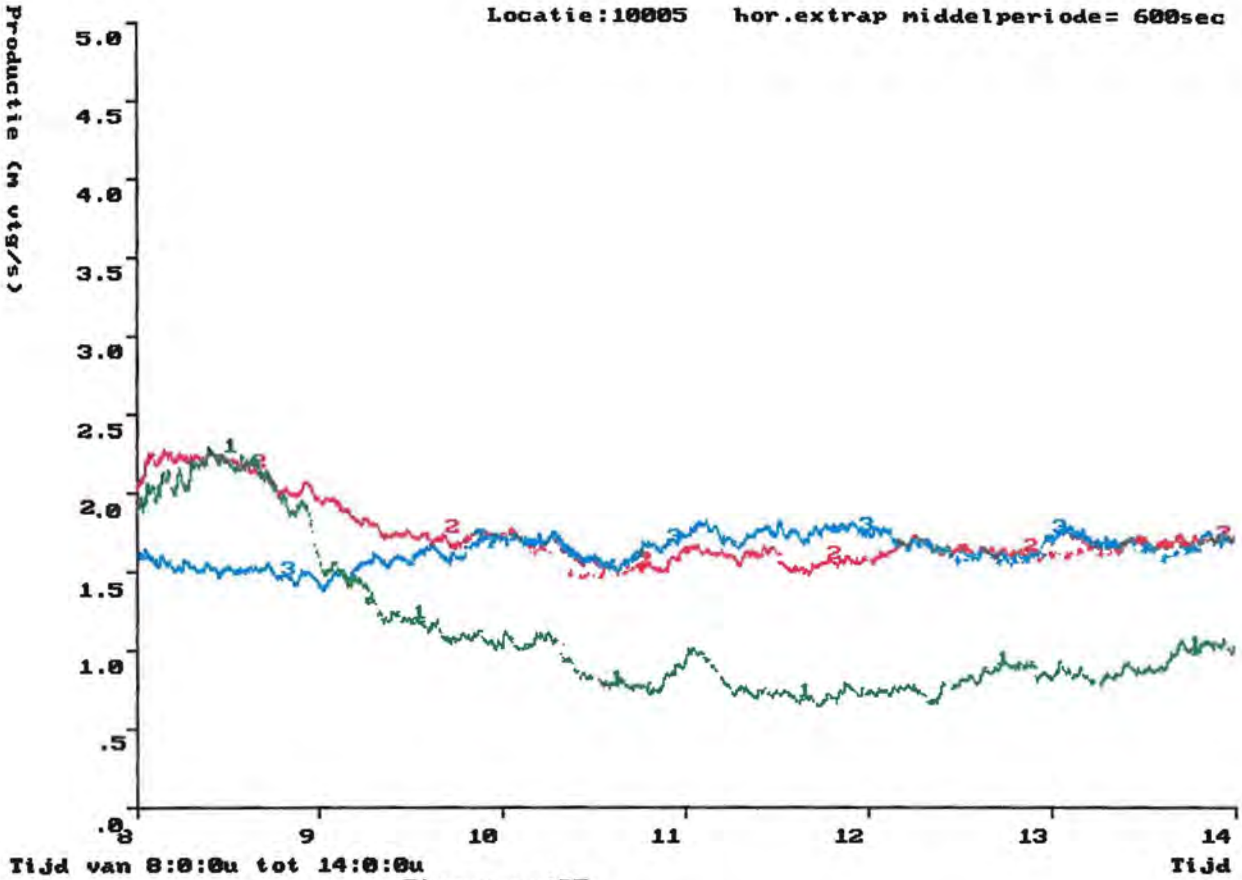

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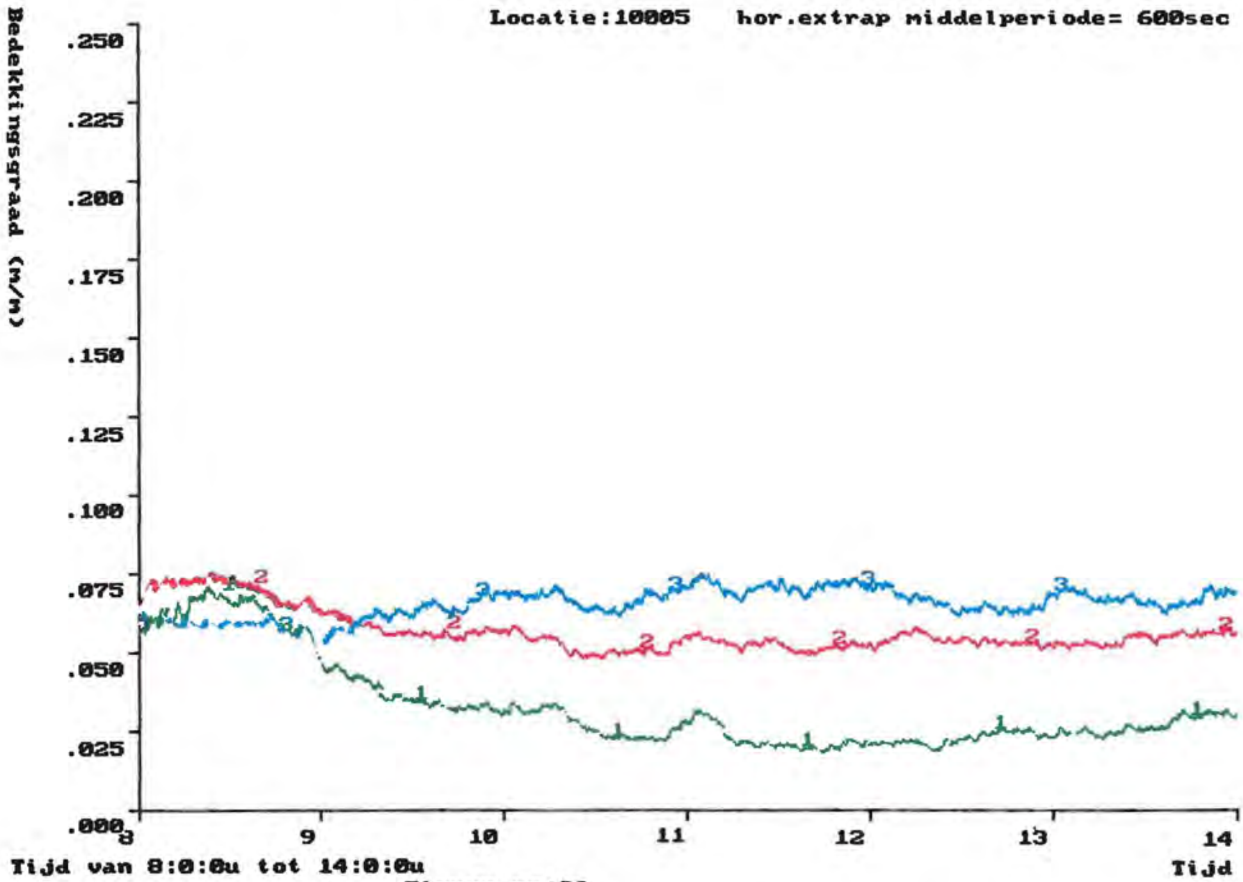

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