Kipp's 100-year Journey

From Moll's Galvanometers to Chart- and Data Acquisition Recorders

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Introduction

When we documented[2] the ongoing activities of the Dutch physicist W.J.H. Moll with Kipp & Zonen in Delft, our focus was primarily on research and development of thermopiles. We described how Moll's work and that of others with Kipp since 1913 had progressed into a world-leader in measuring solar radiation.

In a few footnotes[3], we also mentioned Moll's activities on his galvanometers, which later evolved into Kipp data recorders. When investigating this in more detail, we realized that - in parallel to the thermopile track – Moll's galvanometer efforts and subsequent developments by Kipp & Zonen progressed into a 100-year journey. These activities did peak in 1985 when recorder sales turned to be 90% of Kipp's total annual sale. However, unlike the solar and atmospheric instruments, this was halted in 2013, when Kipp's latest model of data acquisition recorder was discontinued and transferred to another company.

The Kipp galvanometer-to-recorder itself has been an almost continuous cycle of research/design/implementation, in a series of step-by-step developments. Each time, this was marked with a new or improved instrument, keeping up-to-date with the latest techniques. Starting from a highly sensitive Kipp galvanometer, the device was extended and expanded with optical amplifiers, initially using radio valves to be able to detect even smaller signals. Next generations took over using individual transistors, later by integrated circuits (IC's) and microprocessors. At the same time, the functionality of the devices drastically increased. Where the first models 'just' recorded signals, later versions 'treated' signals before displaying results. An initial, single channel recording micro-voltmeter released in 1955, weighing over 40 kg apparatus, eventually took over (in 1996) to become a rugged, industrial 8 parallel system at just 2 kg per channel, where data could be digitized, stored and off-loaded at a later stage.

Moll's Galvanometers with Kipp

Galvanometers are instruments that are used to indicate or measure (very) small currents or voltages in bridging circuits, potentiometers and other measuring equipment. designed for special purposes, these signals are usually of a short period or transient, low frequent nature.

In early 1913, Kipp & Zonen started the production with its first series of Moll mirror coil galvanometers (Fig. 1); a light coil in a strong electromagnetic field ensured a very rapid – 2 seconds- indication.[4,5]

By 1917 Moll's galvanometer range with Kipp had been extended with a permanent magnet version.

In 1929, Kipp issued an overview of the various galvanometers, available in its portfolio. Most of these galvanometers were developed by Moll, as a follow-up to his initial instruments. New were his torsion string[6] - and vibrator galvanometer.[7] Also, a 'micro Moll' version, with stretched and smaller wires to provide short period measurements, was added (Fig. 2).

Other galvanometers, produced by Kipp and marked as 'type Z'[8], were designed by prof. F. Zernike from Groningen, who later received the 1953 Nobel Prize in physics for his invention of the phase contrast microscope.

Fig. 1 *Moll coil mirror galvanometer 1913 – V06652.*

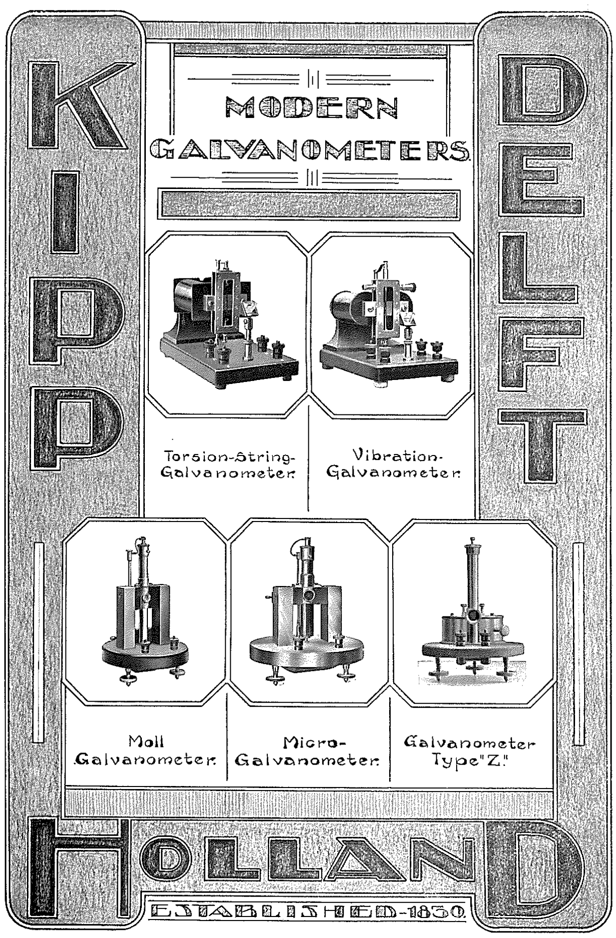

Fig. 2 *Various Kipp galvanometers, card from around 1929.*

Fig. 3 *Kipp Voltamp galvanometer, Microva AL4, 1959 onwards – V32155.*

Kipp's list of galvanometers continued to expand. In the March 1933 version of the Catalogue of Scientific Instruments, the number had grown to eight different types of Moll galvanometers, including a school galvanometer and two instruments that Moll had developed with H.C. Burger and W.J.D van Dyck, colleagues from Utrecht University.

Light Spot Galvanometer

Because of their high sensitivity, Moll's galvanometers were always mirror galvanometers. A small, separate lamp would be shining onto the mirror, onwards to a scale. Both would be mounted at some distance – typical 0.5 to 1 metres- from the galvanometer.

Moll's promoter prof WH Julius[9] had already developed in 1903 – with Kipp – an anti-vibration method[10], in supporting galvanometers, to greatly reduce the impact of the Utrecht tram, near the University Physics building.

In 1936, as a novelty, Kipp issued a compact, stand-alone version[11]. It consisted of a simple, small wooden box, inside a Moll galvanometer, a lamp and a screen, to read off the reflected light spot. In 1946, the first fully integrated Kipp portable light spot galvanometer was released. In this device lamp, mirror and screen were incorporated into one single robust cast metal housing.[12]

By 1955, Kipp issued an overview[13] of its full range of galvanometers, as a function of Amps and Volts. Clearly, Kipp wanted to ensure that customers would know it offered a solution 'for every question'.

In 1959, the integrated galvanometer was developed into a new 'Microva'[14] mirror galvanometer with various damping factors. A highlight was the light spot galvanometer Microva AL4. (Fig. 3) It was able to measure both various voltages as well as current ranges, without reconnecting the instrument. It was marketed as a calibrated multi-range galvanometer – an improvement over competitors, such as Radiometer, Denmark and Greibach, USA, who still had to use separate meters.

The Microva instrument itself was an example of industrial design.[15] Here the instrument was no longer defined by the abilities of the foundry, but developed on basis of a functional 'look and feel' approach, using sheet metal.

The popularity of this type of instruments was evident when on 29 March 1974 Kipp delivered its 25.000th Moll galvanometer, to be included in the Microva and its successors.

From Photographical Registration Drums to Chart Recorders

Whereas galvanometer readings had to be collected manually, results had to be recorded and written down. In his photometric lab in Utrecht, Moll had already been working alone on a solution to record results automatically.

By 1915, he was able to register the galvanometer light spot directly onto silver-bromide paper.[16] By 1919, Kipp had produced a photographic recorder, designed by Moll. Within 10 years, the company had produced and sold 75 recorders, mainly as part of Moll's microphotometer.[17] All in all, this technology was used for almost 40 years, when various drums could handle different lengths of bromide paper.

Apart from bromide registration, there was a growing need to be able to record small signals – typical 10 mVolt full scale - *on paper*, using pencil or ink for a longer period of time.

Initially, Kipp had to use instruments made by others to record results on paper. As an example, Gorczynski's pyrheliometer, which includes a Moll/Kipp thermopile, used in 1924 a sensitive galvanometer and a registering millivolt meter from Julius Richard, Paris. The galvanometer was connected with a clock-rotating drum (e.g. 24 hour), covered by paper. Using a drop bar, the needle of the galvanometer would be pressed at regular intervals on ink-ribbon and paper, causing a stream of dashes. The key problem, however, remained the limited sensitivity of the needle galvanometer.

In their catalogue of 1938, Kipp offered a registration instrument, made by the British

Fig. 4 *Kipp Delft galvanometer production workshop, 1955.*

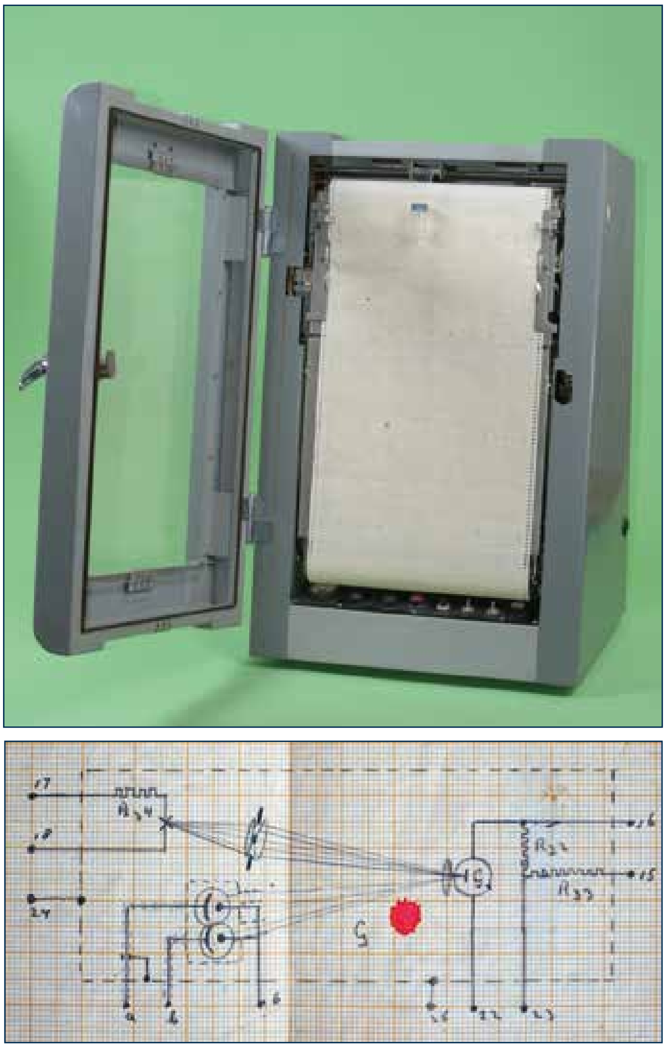

Fig. 5 *Kipp recorder* (a) *Micrograph C42, 1955 – V32135;* (b) *detail input circuit: photocells and light beam.*

Fig. 6 *Kipp recorder BD2 1959 – V32166.*

instrument maker Cambridge, to handle 7 mV full-scale. It was equipped with a paper roll that would continue to record until the end of the roll was reached.

In 1953, Kipp issued its own paper-writer for registration at small values, 8 mV full-scale (C37). Their version also had a drop bar and ink-ribbon[18] to impress onto the paper. Paper transport was still driven by clockwork.

In the meantime, the company was investigating a much more advanced recorder. From a personal log, held by one of the Kipp engineers[19], it transpired that since 1952, Kipp was deeply involved in developing a much more sensitive device (Fig. 4).

The results became public in 1955, when a new generation writer – the Micrograph C42 (Fig. 5) – was released.

It consisted of a mirror galvanometer, an optical amplifier, a potentiometer and a paper- or chart recorder. Three paper speeds were now controlled by a synchronous motor via a gearbox.

The input signal was still received by a mirror galvanometer, as in their 1936 version. However, as soon as the galvanometer would move, a series of photodiodes, coupled with a valve amplifier, would drive a servomotor connected with a potentiometer. In turn, the potentiometer would generate a compensating signal to the galvanometer, reducing it to zero. In fact the compensating signal becomes equal to the input signal. In this method, also high-resistance sensors could be read out, as the current would be zero when the correct pen position is achieved. The input impedance is therefore very high.[20] The result of this approach is that the ink-pen on paper, connected to the sliding contact of the potentiometer, very accurately follows the input signal.

This instrument achieved a galvanometer sensitivity of some 50 microVolt full-scale. Compared to Kipp's 1953 writer, the sensitivity of this instrument is 160 times, a major step forward. To achieve this result, however, the weight of the instrument became over 40 kilograms! Valves and other electrical equipment were necessary for the optical amplifier.[21]

To ensure the input signal was 'floating', batteries powered the input circuit of galvanometer and compensating potentiometer. Clients of this instrument would at times have forgotten that a battery was involved, which could become empty. Users would contact Kipp in panic, stating that their instrument was acting very 'weird'.

Because of the high sensitivity provided by this new device, the Micrograph, at a cost of NLG (Dutch guilders) 3150, rapidly became a preferred method to store results on paper charts for a large range of industrial and scientific applications.

By 1958, the initial version of the Micrograph was sold out. A new, more compact design was announced (Fig. 6)[22] again with a synchronous motor, but with different pairs of gearing wheels to achieve various fixed paper speeds. Production however was very slow, as it took months to commence delivery.

Despite the modern looks, the instrument was still based on a galvanometer/optical servo system.

By 1960, this instrument was responsible for well over 30 % of Kipp's sales. Whereas initial recorders could only handle a single channel, in 1962 a multi-channel input selector was introduced. It allowed up to 4 input signals, to be sampled one-at-the-time, as if these signals were recorded continuously.[23] Additional tools, such as an integrating unit, supported the versatility of Kipp's chart recorder.[24]

As Kipp's business grew, in July 1963 its offices moved from the Oude Delft 200 Voorstraat 67-75, in the centre of Delft, to a modern factory at the Mercuriusweg 1, at that time[25] just on the outskirt the center of the city.[26]

In 1964 in the Netherlands alone, some 300 Micrographs were sold, primarily to industrial - and scientific laboratories.[27] As demand continued to grow, delivery times had gone up to 3 and later even to 6 months.

To accommodate these delays, Kipp aimed to create more production capacity for their Micrograph line. Despite significant efforts, well-trained staff was hard to find. Even available housing to attract new staff was limited.[28]

Fig. 7 *BD5 - First recorder with semiconductor input 1968 – V32128.*

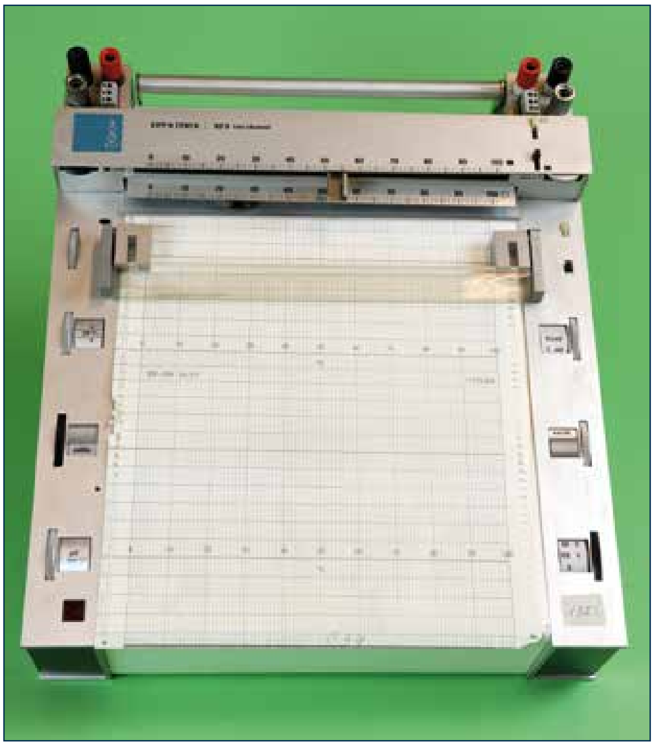

Fig. 8 *Kipp BD9 two-channel flatbed, 1973 – V32152.*

Kipp therefore decided to create Micrograph production time by reducing some other instruments from their program.[29]

Ongoing rationalization also enabled Kipp to improve its production capacity; whereas the initial Micrograph unit took some 100 man-hours to complete, later versions reduced production time to 80 hrs. By 1965 – 10 years after the introduction of the instrument- this was further reduced to 70 man-hours.[30]

In that year, Kipp also announced the introduction of a dedicated sales manager[31]; research activities became more focused on customer requirements, collected from client feedback.

By 1966, Kipp had developed a new version of the Micrograph[32] with an improved sensitivity of 20 microVolt full scale, 2.5 times better than the initial version. Several years of experimental work were required to achieve a highly reliable automatic zero suppression, before this feature could be released into to the market. One of the returning problems of previous versions of the Micrograph, a slow input drift, could thus be resolved.

Whereas previous versions of the Micrograph were designed using electrical valves, the new Micrograph BD5 (Fig. 7) had an input circuit using field-effect transistors (FET), a novel semiconductor technology transistor.[33] The solution of Kipp's R&D manager Petersen would be later patented in various countries

In 1968, Kipp introduced a further extension of the Micrograph line: unlike the automatic channel selector of 1962, the new version offered the recording of two fully independent channels, each with its own pens[34] yet the same input characteristics as its predecessor.

In May 1970[35], Kipp's director H.W. Ankersmit[36] told his staff that the company was sold to its next-door neighbour, Enraf-Nonius.[37] As Ankersmit did not have a family member who wanted to succeed him, he was very concerned about the future of the company. By selling Kipp to Enraf, he hoped that his company would benefit from the excellent connections that Enraf already had with companies such as DSM, Hoogovens and Akzo.[38] After the transaction to the new owner, Ankersmit remained Kipp's director. Rob Jans, an Enraf employee, became Kipp's vice-president, in charge of day-to-day activities.

In the same year when Kipp became part of Enraf, the company introduced a new type of chart recorder, BD7. The concept of the vertical drawing table, as was applied since 1955, was left. Instead, to allow easy handwriting and marking on the recorder, a horizontal writing table was created by a so-called 'flatbed'.[39] The design of the Kipp flatbed itself was very much a matter between the production manager and the drawing department: the manager thought it to be a cheap solution and the drawing people finalized the concept.[40] Over the years, this concept, essentially based on aluminum profiles, became implemented in a series of flatbeds: apart from a single-channel version, a double channel version, including an integrated option was released (Fig. 8).[41]

In 1975, Kipp started to develop a 'next generation' data collection system. The idea was to record *and* process input data, while outputting results at a later time.

Measured signals would be collected via an 'analogue-to-digital' converter, followed by processing and storing on a cassette.[42] At a later stage, the digital signal would be converted back to an analogue signal. While this concept had ample opportunities – in fact a pre-cursor of current data loggers – Kipp decided to not to progress this project further.[43]

So far, all Kipp's recorders were based on input signals as a function of time, i.e. (X,T). In April 1976, the company introduced an (X,Y) recorder. With the introduction of this type recorder two input signals would be drawn, plotting the channel X against channel Y.[44]

In 1976, a new generation of (X,T) recorders BD40/41 (Fig. 9) was introduced[45], replacing those developed in 1970 onwards – in part because of their increasing, prohibitive labour costs to produce, each individual printed circuits and connecting cable harnesses. The new generation, released as a compact, ergonomic design data recorder, turned out to be one of Kipp's best-sold recorder ever.

Kipp also latched on to recorders using both printing and plotting at the same time. Examples were printing of a (regional) peak value, while plotting underlying curves. This

Fig. 9 *Kipp BD40 single channel recorder, 1976 – V32130.*

required some very versatile 'managing' of data and logic for electronics and paper transport, utilizing a 5x9 matrix character generator. Initially (1980), this process was controlled using TTL[46] and A/D convertor but later (1984) using a microprocessor[47] into 'intelligent thermal printer/plotter' with one or two input channels.[48,49]

To alleviate a growing unemployment in East Groningen, north of the Netherlands, in 1980 the Dutch Government encouraged local economic developments by funding specific employment. The CEO of Enraf - Kipp's parent company – saw this as an opportunity with scope for some 10 instrument manufacturing facilities in that area. The Dutch Prime Minister Van Agt immediately visited Enraf head-office in Delft to support their initiatives. After numerous calculations and various internal discussions, Enraf decided that Kipp would develop a new type of recorder, a printer/plotter to be constructed in the Veendam factory.[50,51]

Apart from the instruments made and sold under Kipp's own name, some of these recorders such as BD40, BD50 or BD60 were sold under a different logo and vendor. In that way thousands of recorders were delivered as OEM[52] to various firms such as Pharmacia and LKB of Sweden[53], Mettler, Switzerland and Fisher Scientific USA. In particular for the BD40/41, this recorder was sold under OEM by 10 different vendors.

By 1983, Kipp developed two state-of-the-art recorders. Firstly, it released the well-designed (X,Y) BD90/91 (Fig. 10) recorders. At the same time, it announced the (X,T) BD100/101 version. Both recorders followed a modular approach[54] where channels boards could be plugged into the main board. The BD100/101 series offered up to 6 channels, with pens writing on a folding paper book.[55]

An interesting feature of the Kipp recorder was a 'pen offset compensation' to electronically compensate a position-misfit between individual ink-pens, relative to the timescale.

The company ODME, a 'spin-off' of Philips near Eindhoven, bought many BD101 recorders in support of their CD and CD-rom production industry.

In 1985 Kipp's portfolio consisted almost entirely of different types of data recorders; 90% or NLG 4.3 mln (of Kipp sales were recorders.

In 1989, Kipp released a new, sleek flatbed recorder BD111/112 (Fig. 11)[56] with a synthetic cover. At the 1989 Pittsburg conference, even the competition thought it was the "winner". The housing of this recorder was developed by Karel Suyling, the designer who had worked on-and-off with Kipp since 1956. The flat- and thin frame initially caused serious production challenges to accommodate all electronic equipment in a limited space.[57] The recorder motors were tiny, yet robust, originally designed by Maxon for the automotive industry.[58]

On 8 February 1990, Delft Instrument was established, following a merger of Oldelft and Enraf-Nonius. Kipp & Zonen thus – through its link with Enraf-Nonius- became part of the

Fig. 10 *Kipp BD91 (X,Y) A3 recorder 1983 – V32165.*

Fig. 11 *Kipp two channel BD112 flatbed recorder – 1989 – photo Kipp & Zonen.*

Delft Instrument group.

In March 1991, during the first Gulf War, American forces had found a state-of-the art thermal camera, supporting Iraqi tanks. This camera, which was developed with American technology, was produced by Oldelft. Delivery of this technology to Iraq, however, was strictly forbidden. The American government subsequently banned export of equipment to Delft Instrument.[59] Delft Instruments had to rearrange its export, while production of military equipment had to be stopped.

Kipp – as one of the Delft Instruments companies – also became part of DoT's denial list, causing sales of Kipp products to governmental agencies to become impossible. Also American licenses and technology inside other Kipp instruments had to be strictly limited.[60]

In 1992, the consultancy company Arthur D. Little (ADL) was brought in to implement and support a 'turn-around', including an urgent need to make a profit.

For Kipp, this implied that the Veendam facility had to be closed, while the remaining production would have to be transferred to its Delft facility. Kipp's recorder activity itself had to be refocused on 'milking' existing recorder efforts, while becoming a 'sole' provider. Also, the sensor technology had to be broadened and expanded, to become a key Kipp activity.

In 1993, Kipp was able to extend its range of recorders beyond its own developed production, when it acquired the data recorder line of Philips Almelo. Philips had developed comparable industrial instruments before its closure.

Kipp & Zonen had reinforced its position as market leader for the flatbed recorders with its state of the art model BD111/112.

Meanwhile, development of a new programmable, micro- processor controlled multi-pen recorder with a step-motor servo-drive was well underway. After 2 years of R&D, Kipp released a new industrial data recorder. Key features were an 8 channel input, with an LCD output screen and interface, both with a disc and paper display with 8 ink pens of different colour. After the introduction at a Dusseldorf trade fair in late 1992, production of the BD200 started in June 1993.

In 1994, Kipp commemorated that it was 40 years since the first data recorder on paper had been released: '40 years expert in recording'.[61]

In the same year, 'cost reduction' (i.e. cost per channel) became a key theme; internationally operating companies, such as ABB/Goerz and Linseis, were heavily competing with Kipp on BD200 in the industrial segment. Increased competition was further caused by a downturn in demand in the previous year; the market for these recorders in Germany alone was reduced by some 30%. One of Kipp's largest OEM-buyer Pharmacia continued to delay purchase of their recorders. Later that year, another Kipp competitor, Sefram, France, joined the price race, when it reduced its recorder prices by 40%.

In May 1995, Kipp moved into the Enraf-Nonius facilities, when the Kipp building became head office and showroom for all products[62] of the Delft Instruments Group. Notwithstanding a strong competition, Kipp did initiate dedicated BD200 projects with rail track builders Plasser & Theurer and with Matisa. Both companies saw the value of this industrial data recorder, forecasting growth over a number of years.[63]

In September 1995, the Dutch weekly *TW*[64] published an article comparing (hardware) data recorders with a software solution.[65] The article cited positive experiences produced using a PC with a data-acquisition board and the software package Lab-View; although relatively slow, six analogue input signals could be accommodated and processed while results would be stored in a database.[66]

Three weeks later, at the request of Delft Instruments management ADL did a second review. Outcomes of the 1991 recommendations were not fully met; the new review was to improve the results. For Kipp, the strategy on chart recorders had to be continued, where possible by taking over competitors. For data acquisition recorders, the strategy was to focus on application niches.[67]

To Data Acquisition Recorders

By late 1996, Kipp introduced the BD300[68], replacing the BD200 recorder; the not fully developed BD200 had become a bad image.

The BD 300 was still able to sample and log 8 signals simultaneously onto a diskette (1.4 MB). Real-time display of the signals was done on a paper roll.

The concept of data logging, which Kipp had initiated in 1975 using Philips cassette equipment, but had to be cancelled for lack of belief by marketing, had finally materialized with the BD300 (Fig. 12).

Kipp saw its sales increasing over the years to hundreds of BD300 units, including those via Austrian Plasser & Theurer, when Deutsche Bundesbahn had approved the BD300 for track train registration and maintenance.[69,70]

In the same year, Delft Instruments sold Kipp & Zonen to the Canadian company SCI-TEC.[71] They integrated their atmospheric Brewer Ozone Spectrometer with Kipp's pyrano- and pyrheliometers into a new solar line. The data recorder line became a separate line within SCI-TEC.

By 1998, recorder sales stood at about 4.2 million NLG.[72]

In early 2000, Kipp further broadened its data recorder portfolio, when it acquired Servogor with various recorders[73] from the Swiss company LEM.

As with the recorder products from Philips in 1993, by securing Servogor, Kipp's goal was to be a single supplier for multiple recording applications.

Fig. 12 *Kipp BD300 data acquisition recorder, 1996 onwards – photo Kipp & Zonen.*

By the end of 2001, Kipp was clearly moving towards this objective, as it was now able to offer some 15 different types of (X,T) and (X,Y) recorders, either their own or under OEM.

In 2002 Eko of Japan and Kipp & Zonen entered into a strategic marketing agreement. Eko, a former agent for Kipp who had become a proper competitor in radiometry instruments, bought 19% share of Kipp with the agreement of exchanging knowledge on know-how between both companies.

In November 2002, Kipp's Strategic Plan fully recognized the recorder reality: the recorder market was shrinking. Kipp should therefore transfer to paperless recorders and data acquisition systems. Paper data recorders should be 'milked' as much as possible in the coming years. By contrast, the solar energy market had much potential.

In 2003, the company implemented serious reductions in its recorder staff. Also, as of August 1, 2003, the building, which Kipp still occupied, became the property of the Delft Municipality, ahead of the railway tunnel project behind the building.

In early 2004, SCI-TEC went bankrupt. A Canadian investor had put the bankrupt company with branches in Saskatoon, Canada and Delft, up for sale. Various potential buyers were only interested in Kipp's solar line, not in the data recording business.

In April 2004, Eko walked away from the deal with Kipp[74]

With help of the former Canadian board of directors, Kipp & Zonen returned back into private hands, buying out the Canadian investment company.

By end of 2004, after 16 years, the company's finances became positive again. All 41 remaining staff received a bonus in recognition of the positive performance. Kipp's solar line sales stood at 4.5 million NLG, while recorder sales had reduced to 2.2 million NLG, half to what it was in 1998. The capacity of Kipp's recorder production lines became further negatively impacted when a lead-free tin bath redesign of Servogor - EC requirements - turned out not to be economical. As a consequence, the Servogor recorders production was halted as of end 2005.[75,76]

By 2007, some two/third of Kipp's total sale came from its solar line. The recording side was still alive; annual sales of the data acquisition recorders – the BD300 was now augmented with a USB stick instead of a disk drive to increase its memory capability – and the flatbeds BD11E/12E were still showing healthy results. In later years, with no new developments, their sales number slowly but steadily reduced to less than one hundred units per year.

In 2013, sales and service of Kipp's last data acquisition recording instrument, the BD300, was transferred to Van Renesse Supplies BV.[77]

With a simple press release in July 2013, the 100-year journey that had started in 1913 with Moll's galvanometer activities to data recorders with Kipp & Zonen, came to an end. Kipp's activities became fully focused on its solar and atmospheric measurement business.[78]

Today, the former Kipp & Zonen BD11E/12E flatbeds and BD300 data acquisition recorders are still steadily sold, yet via a different provider and under a different logo.

Notes and References

1. Kees Ruitenbeek retired from Shell in 2012 and is now with Rijksmuseum Boerhaave in Leiden. Leo van Wely is retired from Kipp & Zonen, Delft in 2012. Referenced instruments from the Boerhaave collection are indicated as V06652 etc.

2. Kees Ruitenbeek, Leo van Wely, Moll's thermopiles and Beyond, *Bulletin of the Scientific Instruments Society*, No. 130, 2016, pp. 11–16.

3. *Ibid*., notes 8 and 23.

4. W.J.H. Moll, 'A quick coil galvanometer'*, KNAW, Amsterdam Proc.* (May – June 1913), **15**, pp. 149–152.

5. *Instructie bij galvanometer: ingebruikstelling van de spoelgalvanometer volgens Dr. Moll*, BOERH cg 1716827.

6. W.J.D. van Dyck, 'A new sensitive galvanometer of short period and low resistance', *J of Scient Instr,* **4** (1926), pp. 2, 56–57.

7. W.J.H. Moll, 'A new vibration galvanometer', *J of Scient Instr*,, **2** (1925), pp.361–363; Also Kipp en Zonen – Vibra25

8. Key feature of Zernike's galvanometer is its high voltage sensitivity. This is attained by suspending the light coil to a thin quartz fibre and by conveying the current to the coil by means of two gold strips. A letter from Kipp to Zernike (collection Zernike UB Groningen) mentions that by 1949 over 1000 Zernike galvanometers had already been produced.

9. W.H. Julius, 1860 – 1925.

10. W.H. Julius, 'Over een inrichting om instrumenten te beveiligen tegen de dreuning van den bodem', *Verslag KAW*, **4** (1895/96), pp. 31–18.

11. Kipp en Zonen RA36, 1936.

12. By 1950, Kipp specially constructed 10 galvanometers to accurately measure microvolt- or milliamp meters for Shell Labs in Amsterdam. These were painted orange (V31919).

13. Kipp en Zonen ABC55, 1955 – Galvanometers and accessories.

14. Kipp en Zonen, Microva (Micro-volt/ampere) AL 1, 2, 3 and 4, released in 1959 onwards.

15. Designed by Karel Suyling. Kipp's director HW Ankersmit met Suyling in 1955. In

1956, Suyling was asked to give Kipp instruments their 'own face', that would last at least 10 years. Over the years 1959 – 1990, Suyling designed various instrument frames for Kipp. Archief Suyling, Citroen, Kipp et all, NAGO, Universiteit Amsterdam, Bijzondere Collecties, 2009.

16. Paper coated with emulsion layer composed of silver bromide, suspended in gelatin.

17. Moll had documented his cooperation with Kipp in 'Wordingsgeschiedenis mijner Instrumenten en de samenwerking met Kipp en Zonen'. Archives Municipality Delft, entry 567, 83. A number of rooms in Moll's house in Soesterberg were set up as a laboratory. In 1927, his health further deteriorated; he died in March 1947.

18. Kipp en Zonen RECO53, Millivoltmètre Enregistreur.

19. Lab journal 1952, W.J. van Vessem, Kipp electrical engineer.

20. Utilising a second or 'repeating' potentiometer with, say 10 Volts full scale, it would become possible to 'amplify' input signals from Microvolts into Volts.

21. In early stages, tube (over-) heating was one of the key issues, causing instability of the circuitry.

22. Kipp News, October 1958 – C42 sold out. New versions with optional 19 inch rack BD1, BD2 and BD3 were only released in late 1959.

23. Kipp & Zonen, Channel selector BA1, 11 12 – Single pen sequentially handles up to 4 channels, 1962.

24. Kipp & Zonen, Integrating device BC1, 1965.

25. The city grew; only a few years later, Kipp's new office was surrounded by other buildings, including flats.

26. The design of the building was from the Dutch architect H.A. Maaskant. The financial write-off of the building was set at 33 years. By 1995, the inside was renovated to accommodate showrooms for Delft Instruments of which Kipp & Zonen since 1970 via Enraf Nonius belonged to. The outside of the building could not be modified, as the building had become 'industrial heritage'. In 1986 Enraf Nonius was introduced to the Amsterdam Exchange.

27. Kipp News, May 1964 – Kipp's foreign agents were encouraged to arrange on-site demonstrations of the instrument for the clients.

28. To have the option to rent 3 or 4 houses each year, Kipp deposited funds at the Delft Municipality, R&D manager, Jaap Boot, could be offered a residence, bought by Kipp.

29. Kipp News, June 1964: e.g. double mirror mono-chromator, designed by De Cittert- was dropped from the list. (V32134).

30. O.A. Ankersmit, 'Geschiedenis Kipp & Zonen 1830 – 1965'. Company history, no official issue. Library Rijksmuseum Boerhaave, S 10532, p. 83.

31. Kipp Newsletter 124, March 1965: Dr FC De Vos becomes full-time manager, before mostly involved in research.

32. Kipp announced the Micrograph BD5 in November 1965. However because of teething problems in the electronic input stage, first series could only be offered two years later in November 1967. First delivery was October 1968.

33. B. Petersen and Kipp & Zonen, Delft, 'Electronic chopper utilising a field transistor switch', US Patent 3,522,519, 1970; B. Petersen and Kipp & Zonen, Delft, 'Self-compensating servo system', US Patent 3,510,739, 1970.

34. Micrograph BD6: 2 channels, 1968. Production of this instrument continued until 1974. 'Virtually all of the remarkable features of the single channel BD5 have been incorporated in the BD6'.

35. Meeting with all staff took place on the first working day after Pentecost.

36. In 1955, H.W. Ankersmit had become the only Director of Kipp & Zonen, a position that was held by his father O.A. Ankersmit since 1912. HWA retired in 1980.

37. Enraf-Nonius started in 1925 as 'Eerste Nederlandse Apparaten Fabriek, Enraf', developing equipment for Roentgen application. In 1948, Enraf opened an instrument facility - Nonius - to conduct fine-mechanical measurements.

38. In fact DSM, Akzo and Hoogovens were also major shareholders in Enraf-Nonius.

39. Concept was initiated by Goerz for their product line Servogor.

40. Discontinued in 1976 as growing production costs including labour became prohibitive.

41. In 1973 onwards BD8, 9, 10 (stepping motor), BD11 1 channel (linear / logarithmic plotting), BD12 single input / 2 pen output (input + integrated input). At a trade fair in China, all Kipp & Zonen flatbed recorders on display were bought. The next year, a Chinese version of the BD8 was on the market, yet with lower specifications. Later, also a local BD40 look-alike became available.

42. The first (Philips) portable cassette recordings became available in 1968.

43. Further prototypes of this recorder had been tested in new trucks, collecting fresh milk from individual farms for the milk factory Frico/Domo. The project, however, was not successful for Kipp.

44. BD30 – released in April 1976, yet halted after mechanical problems. Kipp started marketing (X,Y) recorders from Watanabe, Japan and Schessell, UK. By 1983, Kipp designed its own BD90/91 (X,Y) recorder in A3 format.

45. Released in February 1976 onwards: BD40 - 1 channel, BD41 – 2 channels (X,T). Range 1 mV fsd onwards. The two channel version costed NLG 3610.

46. Released in BD50 in late 1980 based on Transistor/Transistor Logic (TTL).

47. Released in 1984, BD60 using microprocessor Z80 controls.

48. Released in 1984, BD 70, 71 – (X,T) for 1 and 2 channels, tailored to OEM.

49. In 1989, BD80 offered a thermal writing system in one instrument: Epson (printing) and HPGL (plotting). IBM was very interested but declined as Kipp was judged to be too small for IBM.

50. Kipp & Zonen Veendam was registered on 21 January 1981 with Chamber of Commerce, Veendam and opened in 1982. BD60 printer/plotters came into production as of 1984. Developers were Ruud Ringoir and Hans Hulsbos. Following various unsuccessful attempts to sell the facility in Veendam, it was closed in July 1992. Activities were concentrated in Delft.

51. In the end, only one facility was opened – *Nederlands Dagblad*, 19 February 1992.

52. OEM – original equipment manufacturer.

53. The merger of Pharmacia and LKB, however negatively impacted the OEM BD41.

54. The concept of adding individual channels was introduced by ABB Group.

55. BD100 3 (BD101: 6) separate channels data acquisition recorders with Position Offset Compensation. This technique was developed by Kipp engineer Michiel Klaasen. In February 1996, BD100/101 recorder production was discontinued. Spares and tools were sold to ECS, Nordhorn. Germany.

56. Microprocessor controlled by a digital stepper motor.

57. BD11E/12E, released in 2001, were trimmed-down versions of the BD111/112. To reduce (competition) unit costs, client-requested calibrated, zero-point suppression was removed. The electrical pen lift and remote control became options. POC in BD112 became a 'free' option.

58. At some point, Kipp was advertising that the BD111/112 engines were the same as those in the Mars Pathfinder, which was successfully driving around on Mars.

59. NRC 12/10/91: Delft Instruments estimates the trade embargo impact to be some NLG 34 mln (34 million Dutch guilders).

60. By 1991, Kipp's total sales were NLG 17 mln.

61. In 1994, flatbed (BD 111/112) sales were satisfactory; an OEM BD112 for pH measurement was delivered as the Beckman CR200 recorder. Sales of industrial data recorders (BD200) were still disappointing.

62. In 1994, Nucletron merged with Delft Instruments Group. The name Delft Instruments remained.

63. The order of P&T for 400 BD200 over 4 years was 80% certain.

64. Mulder, A, 'Paneel metertjes en penschrijvers verslagen door software', *Technisch Weekblad,* 12, 6 September, 1995.

65. Labview by National Instruments of America.

66. The arrival of Labview caused concerns within Kipp as it was not at all clear whether/how quick customers would transfer from e.g. Kipp recorders to a Labview solution.

67. ADL review sensor strategy: develop where possible, profitable in Europe/ Australia/ Japan and expand market share in US and China.

68. After the project phase, the name BD92 was changed into BD200 SPARC - Special Purpose Acquisition Recorder Computer- and later became BD300. In particular the name 'SPARC' had to be dropped at the express request of Sun Microsystems USA.

69. P&T has proprietary soft- and hardware to carry out dedicated calculations, required for laying and validating positioning of train rail tracks. The combined dedicated hard- and software with the BD300 was only available through P&T.

70. BD300 in OEM to LEM, Siemens, Plasser & Theurer, Matisa and Sefram.

71. SCI-TEC paid some 5 mln CAD (1 CAD = 1.45 NLG in December 1996) for Kipp to Delft Instruments. The transfer of ownership was implemented by end of 1996, retroactive by early 1996. At the occasion of its 170^{th} anniversary, the company name was changed back in 2000 to Kipp & Zonen. Now that Kipp had changed ownership, it rented its premises from Delft Instruments.

72. Financial data according to LEM, as Kipp did not provide information on recorder sales.

73. LEM produced the Servogor 500(520/540)/570 Oscillographic Recorders and Servogor 110/111/112 Portable Battery Recorders in Vienna, Austria.

74. EKO and Kipp Management were discussing financing aspects with Mitsubishi Bank in Amsterdam, when the news came from Canada that bankruptcy had been filed for Kipp & Zonen Inc. Kipp & Zonen BV, however, was protected

75. Later it became clear that this EC requirement was not applicable for this type of electronics.

76. Eventually, in July 2006 Kipp & Zonen moved to the second and third floor of the Delftech tower, near the Delft University Campus.

77. Van Renesse Supplies (VRS) is owned by an ex-Kipp employee and started a business in Kipp spares. In 2009, BD11E/12E were transferred to VRS. Currently, VRS still delivers BD11E, 12E and BD300 to international clients, including - via Carltex - to clients in the USA. The production itself is in Aachen, Germany.

78. We gratefully acknowledge (ex-) Kipp employees, who contributed in clarifying and providing additional details in the completion of this article: Ruud Ringoir, Hans Hulsbos, Henk van Renesse, Piet van Unen, Teun Verhagen and past-director Ben Dieterink.

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