

IBM 2314 Direct Access Storage Facility (DASF)

1965 - 1978



Photo: IBM Corporate Archives

Historical Significance

- Improved cost and capacity enabled adoption of “all on-line” data processing.
- A quadruple capacity replacement for the predecessor 2311 at 29 MB per spindle.
- First IBM use of ferrite core heads for increased recording frequency and areal density.
- 2314 and System-360 facilitated the "plug compatible HDD" industry by IBM competitors
- Introduced IBM marketing of 9-bay drive arrays, placing 8 drives on-line at once

Discussion

The 9 drive 2314 Model 1 DASF, announced April 22, 1965, was a marketing bundle of eight drives, a spare drive and a control unit that preserved a market for the lower priced 2311 which was sold separately. The design was awarded a Design Patent in 1967 (see references). The 2314 from IBM was officially discontinued in October 1978, per the IBM archives. IBM separately shipped the Control Unit, two four-drive modules and a one-drive module; these later became the 2314 Control Unit Model B1, the 2313 four-drive module and the 2312 single-drive module. That configuration lasted until 1969 when IBM “unbundled” IBM hardware from IBM software, in part due to pressure from the Justice department and in part due to price pressure from the PCMs none of whom bundled drives with controllers. At that time IBM announced the 2318, a two-disk drive module. In a competitive response to the PCMs, IBM later announced a lower priced three-drive module, the 2319, which had the effect of lowering its rental per drive price for its new customers while maintaining a higher rental price for drive for its existing customers.

As a technological extension of the 1311/2311 series of drives, the 2314 featured more data capacity and higher performance. The 2314 became the primary disk storage on the System/360, which had been announced the previous year. RPM increased on the 2314 from 1,500 (on the 1311/2311) to 2,400, reducing latency and boosting transfer rate. Although the hydraulic actuator was retained, access

time decreased from 85 to 60 milliseconds. Plug-compatible competitors often used somewhat different technology, such as voice coil actuators but the same disk pack was common to all variants. The 29 MB type 2316 Disk Pack used with the 2314 employed 20 recording surfaces instead of 10 found in the 1316 packs used with 1311/2311. The 2316 disk pack weighed about 10 pounds, large by today's standards, but conveniently handled by most operators.



IBM 2316 Disk Pack

Photo from Roger Broughton Museum, UK – reference 4

With 8 drives on-line, the system had about 240 MB available to the host, an impressive amount of storage for that time. The shipped sub-system weighed 4,290 pounds and consumed 9.1 kW of power. Any 8 of the 9 drives could be active at once, with drive selection involving a simple plastic “ID” plug fitting into a receptacle at the front of the drive.

The 2314's success was due in part to the System/360, announced a year earlier. System/360 standardized interconnections for system components, allowing IBM and competitors to “mix and match” their hardware. The very successful System/360 featured modularity of common and compatible devices across a large range of processors, creating a very large market for 2314 disk drives. Users could now upgrade their system or add devices with relative ease. The resulting large market with standardization of attachment was attractive to manufacturers of plug compatible alternatives (see: Memorex 660) who found they could profitably sell a functionally equivalent or superior product at a lower price, either displacing installed IBM products or denying IBM the sale or lease of add-on system drives.

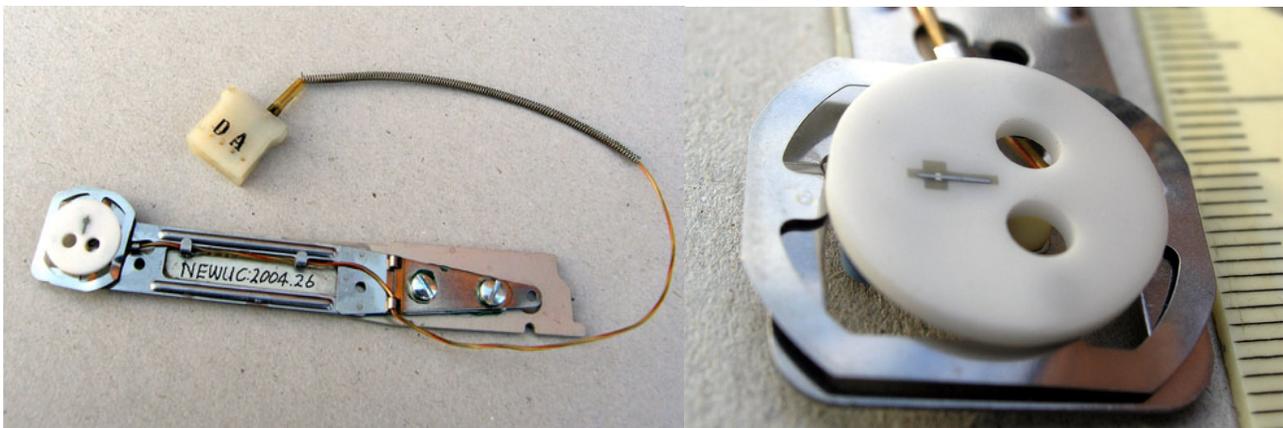
The 2314 was offered on terms that made monthly rental financially more attractive than purchase; its purchase price of \$252,000 was 54 times the net monthly rental of \$5,250 (including a \$76.90 monthly maintenance fee applicable to purchased drives) thus requiring 4.6 years to break even on a cash basis. Similarly, 2316 disk packs had a purchase price of \$650 versus \$20 per month rental. (see IBM pricing data, appendix 1 and 2). Rental was extremely profitable for IBM since the products were expected to have installed lives of five years or more (including re-marketing) but IBM's initial costs were recovered in far less time, perhaps less than a year. IBM pricing created both a large opportunity and a significant problem for its competitors. The opportunity was to install “plug compatible” hardware on large numbers of IBM systems where existing IBM disk drives could be returned after a 30-day notice. The competitor's problems included discounts from IBM's pricing to attract customers, and the need to fund the hardware construction, sometimes requiring borrowed money which could take a long time to recoup the initial investment (plus interest) and show a profit. Additional risks included displacement by another competitor, obsolescence, the need to service the rental equipment, including sales cost to re-rent the returns. It's somewhat ironic that small entrepreneurial companies such as Memorex or CalComp had to borrow money to provide rental equipment and service to wealthy customers such as Bank of America, Pan AM, and Ford. Due to competition, IBM responded with price reductions and product reconfigurations, particularly the 2319, which reduced the profitability of its competitors and

caused some to leave the market. In some cases products were recycled which kept them in service longer than usual. One example is the Memorex 660, a plug compatible 2314 which came off lease in the late 1970s and which was re-sold to DEC who then remarketed them as the RPR02.

The 2314 was likely the first product with a capacity and price point to allow all of a user's data to remain on line, replacing other storage systems in many applications. However, it should be noted that such replacement was discussed as early as 1964 in the context of the 1311 and 1301 disk files. [Ref: Disk File Applications, American Data Processing, Inc., Detroit MI, (c) 1964]

The 2314 introduced both ceramic flying heads and ceramic ferrite cores, replacing stainless steel heads and their Permalloy metallic cores. The ceramic flying head was mechanically more durable than previously used stainless steel, and the ceramic ferrite core gave better high frequency performance. Metallic heads had their metallic cores mechanically "staked" in place, since metals are ductile and could be "swaged" or locked in place. Ceramic components, being brittle, had to be adhesively attached. One disadvantage of the new epoxy bonded head technology was the ability of the core to move slightly within the somewhat flexible plastic encapsulant ... it doesn't take much position change to effect magnetic performance of a pole tip at a nominal flying height of 85 micro-inches from the disk surface. Alternative suppliers of similar heads in the merchant market (e.g. AMC, Infomag) encountered problems of pole tip recession or protrusion (related to the face of the flying head) which drove at least one supplier (Data Industries) out of business. This head design was often referred to as the "Monkey Face" (see photo and patent reference), with two holes to bleed air from between the disk and head, improving lateral stability. The coil spring between the plug and arm surrounded the leads to the head and served as a radio frequency shield. Subsequent technology improvements used glass bonding (first used by IBM on 3330) to eliminate the pole tip movement issue.

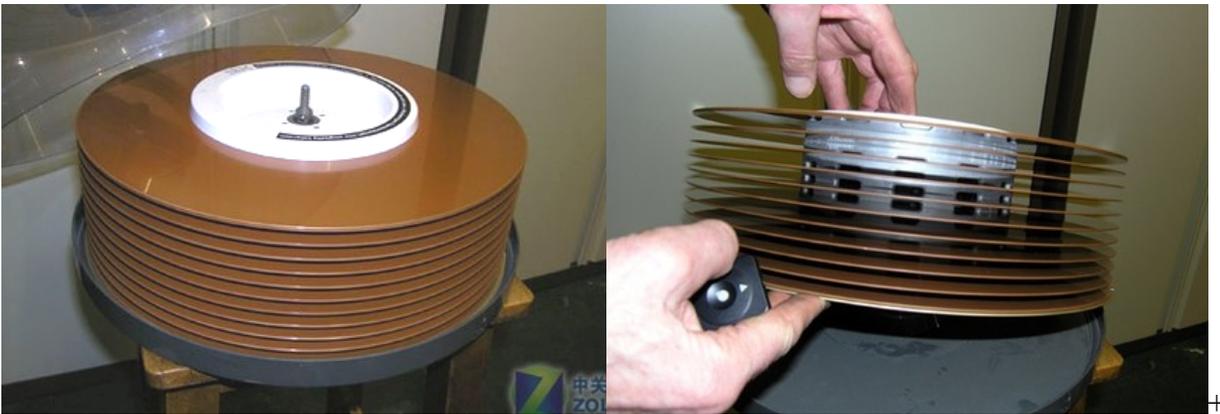
In practice, the heads and disk surfaces were routinely cleaned by field engineers using isopropyl alcohol on a soft cloth held by a tool resembling a "popsicle stick". Signs of trouble would include reddish iron oxide deposits removed from heads and/or disks indicating mechanical interference between the two. If not corrected promptly, this contamination could spread by moving the disk pack from drive to drive. Unfortunately some users experiencing data recovery problems would make the problem worse by mounting the damaged disk pack on multiple drives, contaminating them all, which became referred to as the "Typhoid Mary" syndrome.



IBM 2314 Read/Write Head showing "monkey face" head design (right)
Photos from Roger Broughton Museum, UK – reference 4

The recording principle is equivalent to tape drives of the era, using a magnetic core to both write and read data on the surface. The recordings are surprisingly robust, with data on an original 1950s era RAMAC storage system (currently on display at the Computer History Museum) still readable. The disk pack used magnetic iron oxide in an epoxy-phenolic cross-linked binder, applied by spin-coating a wet slurry onto a slowly spinning aluminum substrate (see patent reference 3,198,657). The disk with its "magnetically painted" surface, was subsequently oven-baked and polished to a smooth surface.

The disk pack was assembled on an aluminum alloy hub, with ventilated spacers between the disks to facilitate air flow into the head-media interface. Air entering the disk pack area was filtered by an automotive-style porous paper filter, to prevent room dust being caught between heads and media. Airborne particles could easily exceed the 85 micro-inch head-to-disk spacing, so had to be controlled. A high-end automotive air filter is quoted at “100% efficient at 3 microns” (or 118 micro-inches), which takes care of most dirt, allowing disk drives to survive in unclean environments—historical anecdotes describe disk packs routinely being used in coal mines and dusty factories. Filtration at IBM was evaluated and tested with various contaminants during 2314 development, and the 2314 disk drive filtering system was subsequently improved with the IBM 3330 to a HEPA (High Efficiency Particulate Arresting) filter for elimination of aerosols/smoke down to 0.3 micrometer (about 12 micro-inches). Some 2314 competitors (e.g. Memorex) adopted HEPA filters for their 2314-compatible drives, providing a reliability advantage. More detail on this issue is provided in the 1311/2311 article, during which product life the engineering work on aerosols and corrective action leading to HEPA filtration was done.



Both photos from Roger Broughton Museum, UK – reference 4

The 2314 also inaugurated IBM’s use of self-clocking FM (2-frequency, or "double frequency") encoding, which was more reliable since timing came from the data on the disk itself (see Patent reference [3,356,934](#)). In this concept, a single frequency is always recorded as the reference signal for the decoder, and data bits are placed between the clock bits. Good news was greater reliability, bad news was 1/2 of the recorded data was consumed for machine timing and thus was unavailable for user data. Subsequent recording schemes, such as MFM and RLL, improved the ratio of user data to clocking data.

A summary of 2314 features:

Highlights:

- First use of ferrite (non-metallic) read/write transducer in a disk drive
- First use of non-metallic (alumina ceramic) flying head or “slider”
- First application of 9 disk drive array (8 active + 1 spare) in one array
- 29 MB per spindle, versus 2.0 MB for 1311 or 7.25 MB for 2311

Shortcomings:

- Increased sensitivity to airborne contamination due to lower flying height
- Greater sensitivity to pole tip recession and protrusion
- Cross-contamination from disk pack swapping, "Typhoid Mary" syndrome
- 20 surfaces to vertically align, greater sensitivity to spindle tilt
- Mechanical hydraulic actuator, final use in an IBM disk drive

Additional information

IBM San Jose, "A Quarter Century Of Innovation", David W. Kean, 1977, CHM accession number: 102687875

See also the [IBM 2314 website](#) and these website locations

1. <http://www.computerhistory.org/revolution/memory-storage/8/259/1046>
2. http://www-03.ibm.com/ibm/history/exhibits/storage/storage_2314.html
3. <http://www.beagleears.com/lars/engineer/comphist/ibm360.htm>
4. <http://www.staff.ncl.ac.uk/roger.broughton/museum/DASD/200426.htm>
5. http://en.wikipedia.org/wiki/IBM_System/360
6. http://bitsavers.org/pdf/ibm/28xx/2844/GA26-3599-6_2314_2844_Component_Description_Nov71.pdf

Relevant IBM Patents

US 3,198,657 "Process for spin coating objects", Philip Kimball, 17 Sep 1964
Des. 208,308 "Data Storage Unit" (2314 array) Donald Wood & Dave Brodsky, 15 Aug 1967
US 3,631,425 "Magnetic Slider with Orifice", Tom Tang, 28dec 1971

Moderator: Bill Carlson

Appendix 1 – IBM 2314 announcement, features & benefits

IBM

Data Processing Division

W. A. Keith

Audio-Visual Services

Promotional Programs

Product Announcement

DD

IBM System/360

2314 Direct Access Storage Facility

Now ... massive direct access storage for System/360 Models 40 thru 75. The IBM 2314 Direct Access Storage Facility provides significantly increased access speeds and a dramatic decrease in cost per byte.

IBM 2314, another instance of IBM's creative approach to direct access storage, continues the tradition of the 1311, 2311 family. A single unit consisting of a control unit plus storage drives in eight independent modules, each with a removable disk pack, the 2314 offers on-line and off-line storage capability that represents a truly remarkable technological advance. The 2314 is attached to System/360 via the Selector Channel; on the Model 40 via Selector Channel 1 only.

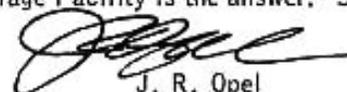
With the new removable and interchangeable 2316 Disk Pack, new horizons are open for direct access storage. Now ... eight disk packs ... 25.87 million bytes or 51.74 million digits per pack ... a total of 207 million bytes on line at all times ... virtually unlimited storage off line.

Highlights ... for Sales Emphasis

- . Each drive operates mechanically and electronically independent of the others as would eight 2311s.
- . File scan and record overflow ... standard features.
- . 75 millisecond - average access time ... 140 millisecond - maximum.
- . Reliability and flexibility ... eight removable and interchangeable disk packs on line per unit. Each pack contains 11 disks.
- . Fast data rate ... 312,000 bytes or 624,000 digits a second.
- . The cylinder concept, retained by the 2314, allows access of 129,384 bytes or 258,768 digits per cylinder on each of the eight modules.
- . Ability to command chain -- multiple records within a cylinder can be read/written by a sequence of channel commands without rotational delay between records. This permits index and directory searches without processor intervention.
- . Unique back-up capability ... a ninth drive in the facility, available for use in the event of preventive or emergency maintenance.
- . Data recorded on eighteen disk surfaces on the 2316 Disk Pack ... 200 tracks per surface ... 7,188 bytes per track.
- . 207 million bytes or 414 million digits can be accessed randomly or sequentially.
- . Up to eight 2314s per Selector Channel ... up to six channels on many systems ... nearly 10 billion bytes ... nearly 20 billion digits.
- . Operating System/360 support committed for the 2841 and 2311 will apply to the 2314.
- . The 10% additional billable time rate applies to the 2314.

See the back of this letter for more information.

Here is the kind of expanded storage capability for System/360 you've been asking for. Fast, economical, flexible, and "open-ended." If you have a customer who needs 200 million or more bytes on line, who can use unlimited storage off line, the IBM 2314 Direct Access Storage Facility is the answer. Sell him today.



J. R. Opel
Vice President - Marketing

Attachments [7]: [1 thru 4] Systems 360.1 thru 360.7 ... [5 thru 7] Machines 2065, 2314-2321, and 2860-2870.

Release Date: April 22, 1965

Distribution: Managers and salesmen (with attachments) ... systems engineers

265-41

Appendix 2 – IBM 2314 Price & delivery schedule

Application Possibilities

Ideal for application areas demanding large, fast direct access storage, the 2314 will have broad customer appeal: in Manufacturing and Aerospace for inventory control, shop scheduling, order entry, and material planning; in Federal Government for communications and message switching, logistics, and supply accounting; in Utilities for customer accounting, gas and electric, and telephone; in Insurance for storage of rate tables, programs, and indexes. The 2314 also has vast application potential in areas where real time, tele-processing, and time sharing systems are required.

Sales Compensation Plan

Selling and installing quota points will be credited in the normal manner for the 2314 Direct Access Storage Facility. In addition, the 2314 will receive 1500 On-Schedule Quota Points (Schedule B) and 2800 Out-of-Territory Quota Points (Schedule D). As is the case with the 1316 Disk Pack, the 2316 Disk Pack will not receive any quota point credit.

Programming Systems Support

The 2314 will be supported under Operating System/360 in the same manner as the 2311.

Delivery Schedule

First customer shipment of the 2314 for System/360 will be 1Q 1967. IACs and MESs must be submitted at least 120 days prior to the scheduled shipping date.

RPQs

RPQs may be submitted immediately. Processing will not begin until 120 days after announcement. Initially, response time will depend upon the complexity of the request.

Publications

Availability of an SRL, "IBM 2314 Direct Access Storage Facility," A26-3599 will be from the Distribution Center on May 1, 1965. A promotional brochure, #520-1130, is available.

Prices

2314 rents for \$5,250, sells for \$252,000; 2316 rents for \$20, sells for \$650.

Program Testing

A testing allowance of 15 hours has been established for the 2314.

Sample Configurations

	<u>Rental</u>	<u>Purchase</u>
System/360 G40 (131K) with Decimal and Floating Point Arithmetic and 1 Selector Channel	\$ 6,965	\$341,050
2302-4 Disk Storage with 2841 Storage Control and 2301 Attachment Feature	8,675	392,750
	<u>\$15,640</u>	<u>\$733,800</u>
System/360 G50 (131K) Decimal and Floating Arithmetic Standard and 1 Selector Channel	10,650	531,300
2314 Direct Access File Facility	5,250	252,000
	<u>\$15,900</u>	<u>\$783,300</u>