1999 DISK/TREND® REPORT

OPTICAL AND REMOVABLE DISK DRIVES

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FOREWORD

This is the first year in which we have combined all types of optical disk drives and flexible disk drives, along with removable rigid disk drives, in a single market study report. Spokesmen for the nine different product groups which have been included tend to talk differently, have different goals in life, and distinctly different technological objectives -- but most of them would be pleased to have the same customers.

The reason why individual data storage utilizing such disparate product technologies have been combined in this report is the factor all have in common: Removability. Not all data storage users need removability, but those who have a functional requirement which is well served by removable disk drives now constitute markets which cannot be overlooked.

It wouldn't be possible to produce this report without extensive experience in all of the product groups involved. Because DISK/TREND has been active in the data storage industry for more than two decades, it has established extensive files on the industry and a data base management system which was essential in organizing and presenting the data for this report on optical and removable disk drives. Annual reports have covered rigid disk drives and floppy disk drives since 1977, with reports on optical disk drives added in 1986.

We are always willing to help you at any time by providing additional information on the industry which we may have available. Your suggestions for improvements in the DISK/TREND Report are always welcome and are sincerely appreciated.

James N. Porter

Robert H. Katzive

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INTRODUCTION

ODD, FDD, RDD -- an unusual combination of removable drives. The ability to remove either the recording disk or the complete drive is the single feature which is common to all of the disk drives included in this report. The recording technologies used in this diverse assembly of optical disk drives, flexible disk drives and rigid magnetic disk drives is varied, but all have found markets with users which have a functional requirement for removable data storage. Although the individual disk drive product groups are markedly dissimilar, several areas of intense competition have emerged, as manufacturers of various types of removable data storage products identify the same target markets.

You will find differences in the way data is organized in each product group, due to variables in markets and product technologies. There are nine different product groups, and some of DISK/TREND's standard table formats have been included in some sections, but not in others. Naturally, the product specifications for each type of product are different from each other, and special tables have been used in some product groups to cover specific situations.

Data direct from the source. DISK/TREND's method in preparing market studies has always been to collect information directly from the sources in the field, and we've followed that procedure in this report. Most of the data included in this report is being published for the first time, and we have also included information in two product sections from the recently published 1999 DISK/TREND Report on rigid disk drives. The product section on rigid disk cartridge drives is the same as the equivalent section from the DISK/TREND Report on rigid disk drives. The section on card format rigid disk drives has been extracted from the broader data base used in the report on rigid disk drives. Everything else is being published for the first time in this report.

It's important to understand selling prices. If the DISK/TREND Report is new to you, please note the definitions used for the relative price differences in each market channel. As in all DISK/TREND Reports, we report revenues for the sale of individual disk drive products at the level of the first public sale, at the estimated net transaction price, whether the sale occurs at the Captive, Distributor or OEM/Integrator level -- to accurately record the value of the business to the original seller.

DISK/TREND ON DISK. The statistical and specification tables are available on floppy disks, as a separately purchased option to buyers of this report. For easy reference, usage instructions are included on the disks and are also available on the DISK/TREND Web site.

SUMMARY: OPTICAL & REMOVABLE DISK DRIVES

Industry size

The extent of the market for removable disk drives of all types and the diversity of the products in use is not generally appreciated. The status and outlook for all of the removable optical and magnetic disk drives is analyzed here for the first time, and it's clear that the group has an important role in the computer industry.

Sales revenues for this diverse group of products topped $9.6 billion in 1998, and the projected total for 2002 is $11.9 billion. The average annual growth in sales revenues during the 1998-2002 period is only 5.4%, but this overall average is the combination of sales patterns as diverse as the products, both up and down. Annual shipments for individual product groups vary from high end optical disk drives with only a few thousand units, to low capacity standard floppy drives, peaking at 122.7 million drives in 2001.

By the close of the current forecast period in 2002, the leading product group is expected to be DVD-ROM drives, with $4.2 billion in sales revenue and 92.8 million in unit shipments, as the read-only DVD format assumes the leadership held by CD-ROM drives at the beginning of the period in 1998. Another group projected to enjoy significant growth is CD/DVD writable optical disk drives, a mixed group of recording technologies which share the 12 centimeter CD/DVD disk format. That product group's 2002 sales revenues are forecasted at $3.3 billion, with shipments of 29.8 million drives, as each type of product battles for market share with product improvements and dropping prices.

After peaking, low capacity floppy drives will still close 2002 with an expected 119.7 million units, but the product group's average unit price is low and going lower, resulting in 2002 sales revenues of $1.1 billion, after declining every year for five years. Rapidly dropping average unit prices will also hold the sales revenue total for high capacity floppy drives to almost $1.1 billion, despite increasing unit shipments. The other four product groups, read/write optical drives less/more than 4 gigabytes and the two rigid disk drive groups, will each have sales revenue totals well below a billion dollars in 2002. Each group serves smaller, more specialized markets, with the best growth potential in new higher capacity optical drives and small card format rigid disk drives.

TABLE 1

CONSOLIDATED WORLDWIDE REVENUES

OPTICAL AND REMOVABLE DISK DRIVES

REVENUE SUMMARY

	REMOVABLE DATA STORAGE REVENUES, BY SHIPMENT DESTINATION ($M)									
	1998		Forecast							
	Revenues		1999		2000		2001		2002	
	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW
U.S. Manufacturers										
Distributor	389.6	571.1	305.3	482.2	290.8	473.3	301.6	482.8	322.8	517.5
OEM/Integrator	254.0	363.6	241.0	353.4	280.6	431.6	336.7	548.3	422.7	700.1
TOTAL U.S. REVENUES	643.6	934.7	546.3	835.6	571.4	904.9	638.3	1,031.1	745.5	1,217.6
Non-U.S. Manufacturers										
Captive	89.9	943.1	86.7	855.7	117.0	948.9	169.1	1,213.9	221.1	1,320.9
Distributor	1,021.3	3,156.8	1,238.9	3,576.5	1,402.1	3,766.3	1,580.4	4,160.7	1,674.2	4,225.4
OEM/Integrator	1,814.0	4,624.1	1,721.7	4,968.6	1,815.5	4,967.9	1,944.2	5,082.4	2,026.1	5,163.9
TOTAL NON-U.S. REVENUES	2,925.2	8,724.0	3,047.3	9,400.8	3,334.6	9,683.1	3,693.7	10,457.0	3,921.4	10,710.2
Worldwide Recap										
TOTAL WORLDWIDE REVENUES	3,568.8	9,658.7	3,593.6	10,236.4	3,906.0	10,588.0	4,332.0	11,488.1	4,666.9	11,927.8

Marketing channels

As new disk drives appear on the scene, and as displacement of older products occurs, the shares for individual sales channels within several product groups are expected to see significant changes during the next few years. However, the combined sales channel totals of the nine product groups included in this report are not expected to undergo major changes, with overall 1999-2002 Distributor sales revenues staying about the same, Captive revenues increasing slightly, and OEM/Integrator revenues declining slightly, but staying in the lead.

The CD-ROM and DVD-ROM product groups are dominated by OEM shipments, since these drives are installed in the majority of today's personal computers, and the PC manufacturers buy the drives directly from the producers. The same pattern has also existed for many years with low capacity standard floppy drives, with drive manufacturers selling a high percentage directly to personal computer manufacturers. Today's high capacity floppy drives started out five years ago as entirely aftermarket add-on products sold through a variety of resale channels, but the build-to-order PC movement has changed that pattern. Almost half of all high capacity floppy drives are now sold initially directly to system manufacturers, and by 2002 the OEM share will top 62%.

In most cases, the market channel pattern for individual product groups is unlikely to undergo significant change during the next few years. Read/write optical drives with more than 4 gigabytes capacities are installed mostly in libraries used in enterprise system applications, with drives sold on an OEM basis for installation in the optical disk libraries. The ODD market for drives less than 4 gigabytes is predominantly the PC add-on aftermarket, sold through Distribution. Rigid disk cartridge drives are also sold almost entirely through Distribution, as add-on products. It's a mixture with CD/DVD writable optical disk drives, with the diverse assortment of products in this group reaching the market through both OEM and Distributor channels.

One group with a currently stable market channel pattern may be subject to future changes: Card format rigid disk drives. A majority of the 1.8" PC Card drives which have dominated this group are sold through Distributors, but the 1" CompactFlash Card drives now becoming available could tilt the scale toward OEM sales, especially during the first few years of market development, as manufacturers of various types of mobile devices buy OEM drives directly.

TABLE 2

CONSOLIDATED WORLDWIDE REVENUES
OPTICAL AND REMOVABLE DISK DRIVES
MARKET CLASS REVIEW

REVENUE SUMMARY

WORLDWIDE REVENUES BY MANUFACTURER TYPE	1998 Revenues $M	1998 %	Forecast 1999 $M	1999 %	2000 $M	2000 %	2001 $M	2001 %	2002 $M	2002 %
U.S. Manufacturers										
Distributor	571.1 -12.6%	5.9%	482.2 -15.6%	4.7%	473.3 -1.8%	4.4%	482.8 +2.0%	4.2%	517.5 +7.2%	4.3%
OEM/Integrator	363.6 +72.0%	3.7%	353.4 -2.8%	3.4%	431.6 +22.1%	4.0%	548.3 +27.0%	4.7%	700.1 +27.7%	5.8%
Total U.S. Manufacturers	934.7 +7.7%	9.6%	835.6 -10.6%	8.1%	904.9 +8.3%	8.4%	1,031.1 +13.9%	8.9%	1,217.6 +18.1%	10.1%
Non-U.S. Manufacturers										
Captive	943.1 +2.5%	9.7%	855.7 -9.3%	8.3%	948.9 +10.9%	8.9%	1,213.9 +27.9%	10.5%	1,320.9 +8.8%	11.0%
Distributor	3,156.8 +.2%	32.6%	3,576.5 +13.3%	34.9%	3,766.3 +5.3%	35.5%	4,160.7 +10.5%	36.2%	4,225.4 +1.6%	35.4%
OEM/Integrator	4,624.1 +2.0%	48.1%	4,968.6 +7.5%	48.7%	4,967.9 --	47.2%	5,082.4 +2.3%	44.4%	5,163.9 +1.6%	43.5%
Total Non-U.S. Manufacturers	8,724.0 +1.4%	90.4%	9,400.8 +7.8%	91.9%	9,683.1 +3.0%	91.6%	10,457.0 +8.0%	91.1%	10,710.2 +2.4%	89.9%
Worldwide Recap										
Captive	943.1 +2.2%	9.8%	855.7 -9.3%	8.4%	948.9 +10.9%	9.0%	1,213.9 +27.9%	10.6%	1,320.9 +8.8%	11.1%
Distributor	3,727.9 -2.0%	38.6%	4,058.7 +8.9%	39.6%	4,239.6 +4.5%	40.0%	4,643.5 +9.5%	40.4%	4,742.9 +2.1%	39.8%
OEM/Integrator	4,987.7 +5.1%	51.6%	5,322.0 +6.7%	52.0%	5,399.5 +1.5%	51.0%	5,630.7 +4.3%	49.0%	5,864.0 +4.1%	49.1%
Total All Manufacturers	9,658.7 +2.0%	100.0%	10,236.4 +6.0%	100.0%	10,588.0 +3.4%	100.0%	11,488.1 +8.5%	100.0%	11,927.8 +3.8%	100.0%

Note: Percentage figures with plus/minus signs refer to year-to-year growth rates.

Product groups

CD-ROM drives continued their strong growth in 1998, up 23.2% to almost 91.9 million units. Revenues declined 15.2% to $4.3 billion due to intense competition from Korean and Taiwanese manufacturers. Displacement of CD-ROM by DVD-ROM has already begun, and 1999 is the peak shipment year for the CD-ROM product group, with shipments expected to grow only 3.3% to 94.9 million drives, while revenues continue to decline, dropping 17.7% to $3.6 billion.

Despite a lamentable lack of DVD-ROM content, DVD-ROM drive shipments grew over 375% to over 5.7 million units in 1998 and are expected to exceed the 13.5 million mark for 1999. The interest of PC system makers, coupled with rapidly declining prices, DVD-ROM support from Windows 98 and the ability of DVD-ROM drives to read CD-ROM media overcame the DVD content shortfall in 1999. In 2002, DVD-ROM shipments will reach 92.8 million units, outnumbering CD-ROM shipments by over 3 to 1. DVD-ROM revenue in 2002, forecasted to reach over $4.2 billion despite rapidly declining prices, will exceed CD-ROM's $803 million revenues by a factor exceeding five. Unfortunately for the drive producers, the industry appears to be launched upon the same speed race that created major instabilities in CD-ROM pricing.

Spurred by rapidly growing CD-RW drive shipments, drive shipments for the CD/DVD writable drive group exceeded 6.1 million units in 1998, and are projected to exceed 29.8 million drives in 2002. However, the mix within the group will be rapidly changing at that time, with CD-RW drive shipments in decline and shipments of DVD writable formats gaining overall share, helped by the release of 4.7 gigabyte writable drives, but still limited by confusion resulting from competition between different recording formats. Group revenues, over $1.3 billion in 1998, are projected to exceed $3.3 billion in 2002.

3.5" optical disk drives, the predominant product type in the Read/Write drives less than 4 gigabytes group, have enjoyed wide usage in Japan's domestic market, but minimal acceptance elsewhere. Competition from other forms of removable storage and the increasing use of networks is expected to shrink the size of that market, as networks reduce the need for a cartridge interchange medium. The expected availability of higher capacity 3.5" drives and continually falling unit prices will keep the market for these optical disk drives alive, but shipments for the group are expected to peak in 2000 at 1.9 million drives, with shipment declines thereafter forecasted through 2002. Competition from several other removable storage products included in this report are expected to provide increasingly difficult competition for small optical disk drives, with the most severe impact from magnetic rigid disk cartridge drives, high capacity floppy drives, and increasingly affordable CD-RW drives, especially when users are involved in applications for which availability of disks usable with CD-ROM drives are involved. As a result, sales revenues for optical disk drives in this product group peaked at $611.5 million in 1998, and are expected to continually decline, reaching the $356 million level in 2002.

Until 1999, almost all of the action in the Read/Write optical drives more than 4 gigabytes product group has been in 12" write-once drives, even though shipments of this category have dropped steadily for several years to only 1,500 units in 1998. With the anticipated initial late 1999 shipments of 5.25" drives in this product group, a reversal of the declining trend is expected, with shipments increasing to 2,800 units in 1999 and to 349,000 units in 2002. Revenues for the group bottomed out in 1998 at $25 million, and are projected to increase to over $356 million in 2000, again on the strength of the projected increase of 5.25" drive shipments.

Rigid cartridge disk drive production was disrupted by the demise of two competitors, SyQuest and Avatar, dropping to under 1.3 million units in 1998 and a further decline to under one million units is expected in 1999. Production is expected to increase in 2000, rising from 1.1 million units in 2000 to 1.8 million units in 2002. Market growth for rigid disk cartridge drives should develop in receptive specialized markets such as multimedia and video applications, plus a variety of business applications. 1998 revenues of $271.1 million are forecasted to dip to $180.6 million in 1999, then slowly rise to $242.5 million in 2002.

The Card format rigid disk drive product group, which saw shipments decline to under 116,000 units in 1998, is expected to see renewed growth beginning in 1999 resulting from the introduction of IBM's 1" diameter "microdrive". Shipments are projected to reach 750,000 units in 2002. Calluna Technology and PCS International, which acquired rights to manufacture certain Integral Peripherals drives after that company went bankrupt in 1998, are the only remaining active 1.8" drive producers in the product group, but at least one other startup company is expecting to begin production of 1" drives in 1999.

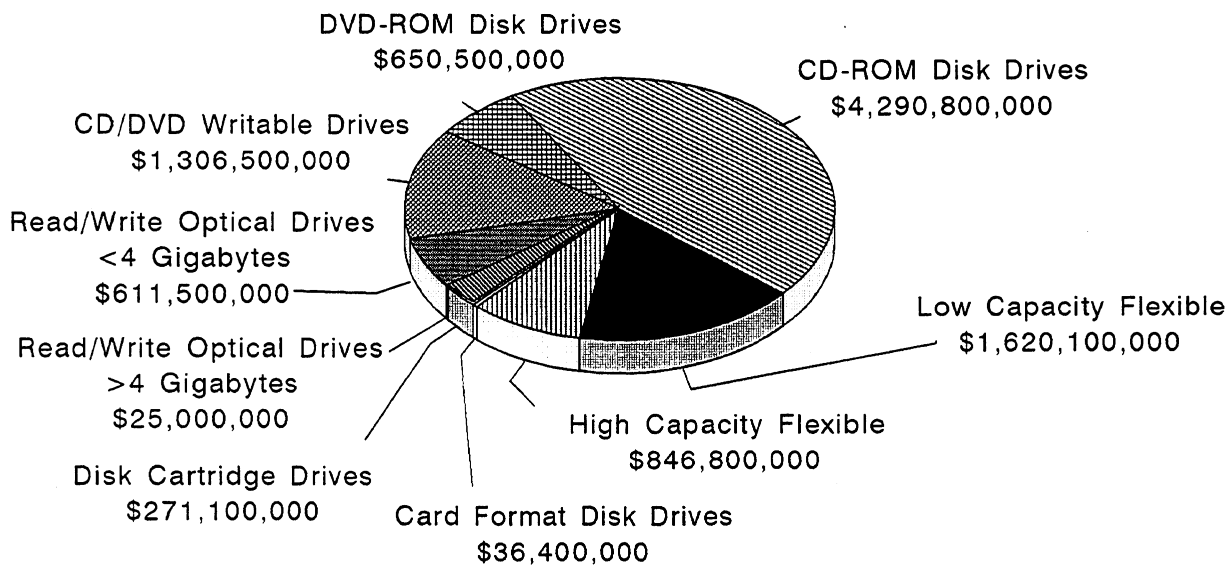
Through 2002, high capacity floppy drives are expected to lead in growth for floppy drives, even though both users and industry exhibit confusion over competition between incompatible standards. The Iomega Zip drive initiated the current growth surge beginning in 1995, followed by the LS-120 in late 1996, with drives currently from Matsushita-Kotobuki Electronics, Mitsubishi Electric and Imation (with contract manufactured drives). An agreement between Swan Instruments and Mitsumi Electric resulted in announcement of a third type of high capacity floppy drive, the 130 megabyte UHC, but it appears this drive will not be produced. Two additional competitors, the Sony HiFD 200 megabyte drive to be manufactured by Sony, TEAC and Alps Electric, and the Caleb Technology high capacity 144 megabyte drive, are expected to reach production in 1999. Shipments of high capacity floppy drives reached nearly 12.8 million units in 1998, with the 2002 total projected at 34.3 million. Growth in sales revenue, however, will be less robust, as average unit selling prices rapidly decay due to intense pressures from system manufacturers and supplier competition. Although unit shipments nearly triple through 2002, sales revenues are projected to eke out only a 27% gain, from $846.8 million in 1998 to slightly over $1 billion in 2002.

Although it doesn't have the glamor of more recently developed forms of removable storage, the standard low capacity floppy drive is still sold in larger quantities, and at lower unit prices, than any other removable media disk drive. However, DISK/TREND forecasts project that future shipment growth for these drives will be limited. Worldwide shipments of low capacity floppy drives for 1998 reached 113.4 million units, up 15.3% over the previous year, but the projected annual increase for the 1999-2002 period will steadily decline, going negative in 2002. Shipments will peak in 2001 with 122.7 million units shipped, then drop to 119.7 million drives in 2002. It is expected that standard 1.44 megabyte 3.5" floppy drives will still be shipped with the majority of desktop personal computers through 2002 but there will be significant displacement by high capacity floppy disk drives in the desktop and notebook PC markets. The pressures on low capacity floppy disk drives will be intensified by the increasing tendency of notebook computer manufacturers to leave floppy drives out of some low end notebook system models.

Figure 1

CHANGING PRODUCT MIX

Worldwide Optical & Removable Disk Drive Revenue



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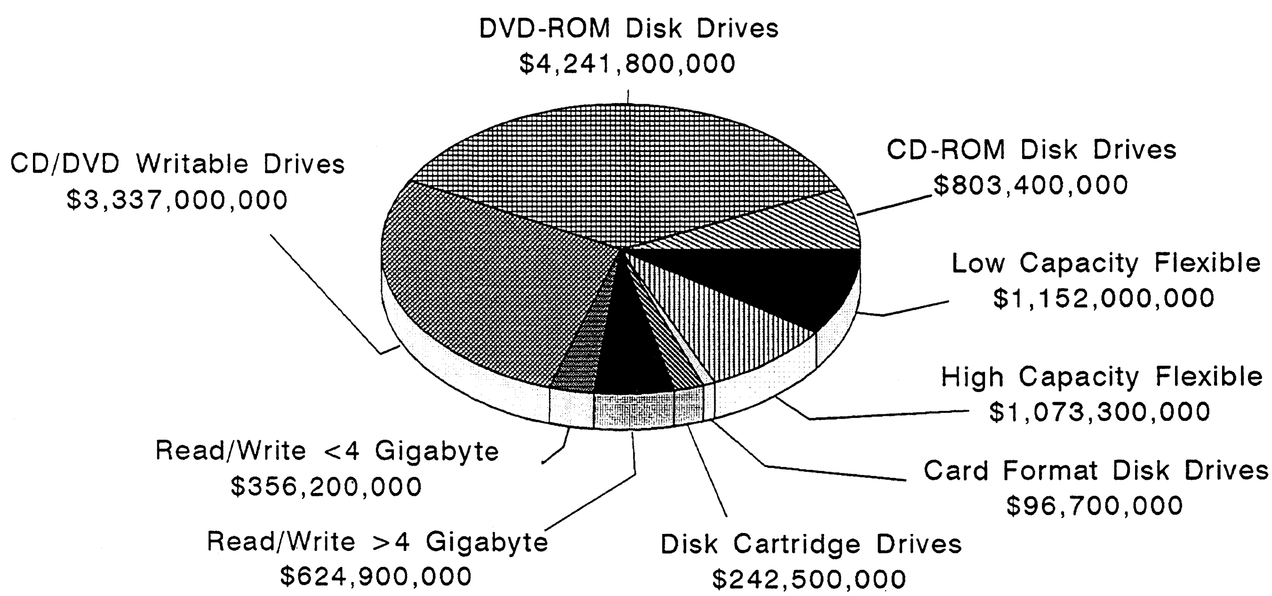

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TABLE 3

CONSOLIDATED WORLDWIDE REVENUES
OPTICAL AND REMOVABLE DISK DRIVES
PRODUCT GROUP REVIEW

REVENUE SUMMARY

WORLDWIDE REVENUES ALL MANUFACTURERS	1998 Revenues $M	1998 Revenues %	Forecast 1999 $M	1999 %	Forecast 2000 $M	2000 %	Forecast 2001 $M	2001 %	Forecast 2002 $M	2002 %
CD-ROM OPTICAL	4,290.8	44.5%	3,529.5	34.5%	2,568.2	24.3%	1,604.7	14.0%	803.4	6.7%
DISK DRIVES	-15.5%		-17.7%		-27.2%		-37.5%		-49.9%	
DVD-ROM OPTICAL	650.5	6.7%	1,198.9	11.7%	1,877.0	17.7%	3,189.4	27.8%	4,241.8	35.6%
DISK DRIVES	+265.2%		+84.3%		+56.6%		+69.9%		+33.0%	
CD/DVD WRITABLE OPTICAL	1,306.5	13.5%	2,207.8	21.6%	2,772.1	26.2%	3,180.8	27.7%	3,337.0	28.0%
DISK DRIVES	+37.4%		+69.0%		+25.6%		+14.7%		+4.9%	
READ/WRITE OPTICAL DRIVES	611.5	6.3%	606.3	5.9%	569.0	5.4%	464.2	4.0%	356.2	3.0%
LESS THAN 4 GIGABYTES	+3.7%		-.9%		-6.2%		-18.4%		-23.3%	
READ/WRITE OPTICAL DRIVES	25.0	.3%	30.6	.3%	139.7	1.3%	387.4	3.4%	624.9	5.2%
MORE THAN 4 GIGABYTES	-29.4%		+22.4%		+356.5%		+177.3%		+61.3%	
RIGID CARTRIDGE	271.1	2.8%	180.6	1.8%	187.9	1.8%	210.5	1.8%	242.5	2.0%
DISK DRIVES	-21.7%		-33.4%		+4.0%		+12.0%		+15.2%	
CARD FORMAT RIGID	36.4	.4%	46.0	.4%	58.1	.5%	80.2	.7%	96.7	.8%
DISK DRIVES	-28.1%		+26.4%		+26.3%		+38.0%		+20.6%	
HIGH CAPACITY FLEXIBLE	846.8	8.8%	944.8	9.2%	1,034.9	9.8%	1,069.3	9.3%	1,073.3	9.0%
DISK DRIVES	+57.0%		+11.6%		+9.5%		+3.3%		+.4%	
LOW CAPACITY FLEXIBLE	1,620.1	16.7%	1,491.9	14.6%	1,381.1	13.0%	1,301.6	11.3%	1,152.0	9.7%
DISK DRIVES	-5.0%		-7.9%		-7.4%		-5.8%		-11.5%	
Total Worldwide Revenue	9,658.7	100.0%	10,236.4	100.0%	10,588.0	100.0%	11,488.1	100.0%	11,927.8	100.0%
	+2.0%		+6.0%		+3.4%		+8.5%		+3.8%	

Note: Percentage figures with plus/minus signs refer to year-to-year growth rates.

TABLE 4

CONSOLIDATED WORLDWIDE SHIPMENTS
OPTICAL AND REMOVABLE DISK DRIVES
PRODUCT GROUP REVIEW

UNIT SHIPMENT SUMMARY

UNIT SHIPMENTS IN THOUSANDS	1998 Shipments		Forecast 1999		Forecast 2000		Forecast 2001		Forecast 2002	
	Units	%	Units	%	Units	%	Units	%	Units	%
CD-ROM OPTICAL	91,892.9	39.4%	94,931.0	36.1%	82,809.2	29.4%	56,849.4	19.0%	30,265.0	9.7%
DISK DRIVES	+23.2%		+3.3%		-12.8%		-31.3%		-46.8%	
DVD-ROM OPTICAL	5,706.4	2.4%	13,351.8	5.1%	30,089.0	10.7%	60,322.7	20.2%	92,832.4	29.8%
DISK DRIVES	+375.9%		+134.0%		+125.4%		+100.5%		+53.9%	
CD/DVD WRITABLE OPTICAL	6,114.7	2.6%	12,574.1	4.8%	18,996.9	6.7%	25,441.7	8.5%	29,805.4	9.6%
DISK DRIVES	+79.1%		+105.6%		+51.1%		+33.9%		+17.2%	
READ/WRITE OPTICAL DRIVES	1,820.2	.8%	1,975.6	.8%	1,908.5	.7%	1,606.4	.5%	1,339.8	.4%
LESS THAN 4 GIGABYTES	+17.1%		+8.5%		-3.4%		-15.8%		-16.6%	
READ/WRITE OPTICAL DRIVES	1.5	--	2.8	--	48.7	--	173.8	.1%	349.0	.1%
MORE THAN 4 GIGABYTES	-37.5%		+86.7%		--		+256.9%		+100.8%	
RIGID CARTRIDGE	1,289.7	.6%	970.0	.4%	1,120.0	.4%	1,410.0	.5%	1,820.0	.6%
DISK DRIVES	-10.4%		-24.8%		+15.5%		+25.9%		+29.1%	
CARD FORMAT RIGID	115.9	--	173.0	.1%	250.0	.1%	475.0	.2%	750.0	.2%
DISK DRIVES	-42.9%		+49.3%		+44.5%		+90.0%		+57.9%	
HIGH CAPACITY FLEXIBLE	12,758.0	5.5%	18,760.0	7.1%	24,290.0	8.6%	29,810.0	10.0%	34,270.0	11.0%
DISK DRIVES	+58.4%		+47.0%		+29.5%		+22.7%		+15.0%	
LOW CAPACITY FLEXIBLE	113,421.0	48.7%	120,232.0	45.6%	122,389.0	43.4%	122,720.0	41.0%	119,725.0	38.5%
DISK DRIVES	+15.3%		+6.0%		+1.8%		+.3%		-2.4%	
Total Worldwide Shipments	233,120.3	100.0%	262,970.3	100.0%	281,901.3	100.0%	298,809.0	100.0%	311,156.4	100.0%
	+23.4%		+12.8%		+7.2%		+6.0%		+4.1%	
% U.S. Manufacturers	4.6%		5.2%		5.9%		6.5%		6.9%	

Note: Percentage figures with plus/minus signs refer to year-to-year growth rates.

Noncaptive market

Noncaptive sales are defined in the DISK/TREND Report as any public sale of a product, except a sale of an internally manufactured product by a computer system manufacturer primarily for use with their own systems. The report classifies noncaptive product shipments as Distributor (sales through distributing organizations, subsystem producers, value-added resellers, retail chains, mail order firms and individual retail dealers) or OEM/Integrator (products sold by the original producer to system manufacturers or system integrators, to be included in complete systems).

Captive sales, in which products are sold by the original manufacturers with their own systems, represent a small portion of the report's sales revenues and unit shipment totals. 1998 worldwide captive sales revenues for all product groups were $943.1 million, only 9.8% of the total, but captive sales revenues in 2002 are projected at over $1.3 billion, or 11.1% of the overall total. Although captive revenues are expected to increase due to expanding use of CD-ROM and DVD-ROM drives in notebook systems made by the same manufacturer, noncaptive sales channels remain the dominant route by which removable disk drives reach the user.

Noncaptive sales of all CD/DVD format drives accounted for 91.9% of shipments and 86.6% of revenues in 1998 and are expected to hold 88.6% of shipments and 85.4% of revenues in 2002. While accounting for a much smaller share of revenue, low capacity floppy drives are, and will remain, the largest noncaptive unit shipment category throughout the forecast period.

The majority of low capacity floppy disk drives, about 62%, are sold through the OEM/Integrator channel, with sales by drive manufacturers directly to manufacturers of personal computers providing the largest market. It is expected that the existing sales pattern will intensify, and about 67% of unit shipments for low capacity floppy drives will be sold to OEM/Integrators in 2002. The marketing channel pattern for high capacity floppy drives, once heavily weighted toward distributors, underwent a transition from dominance by aftermarket sales to growing OEM sales to computer system manufacturers. OEM/Integrator shipments accounted for only 12.3% of 1996 shipments, but soared to 46% of the 1998 total, and are projected to expand to 62% of 2002 unit shipments as prices fall and high capacity drives appear in more desktop and notebook systems.

Distributor sales have historically dominated shipments of rigid disk cartridge drives. SyQuest Technology was the unit shipment leader for a decade, selling its drives primarily in the Distributor channel. Typical customers were a variety of storage subsystem vendors who combine drives with enclosures, cables and software appropriate for specific target system markets. SyQuest was displaced by Iomega and Iomega's Jaz 3.5" drives, but the Jaz series has also found most of its success with aftermarket add-on sales through distribution channels into professional market niche applications. Though the turmoil in this product group has temporarily depressed shipments, a substantial increase in shipments is forecasted for this product group, and it is expected that the market share for OEM shipments will grow, as a variety of specialized system manufacturers add rigid disk cartridge drives as standard system features. However, stronger aftermarket sales are expected to keep Distributor shipments in the lead, declining modestly from 91.2% of the worldwide total in 1998 to 83% in 2002.

3.5" Read/Write optical disk drives tend to follow a Distributor sales pattern similar to that of the rigid disk cartridge drives, in that system manufacturers frequently regard them as nonstandard products, priced at a level above the drives they consider to be industry standard. Sales resistance by system manufacturers confines most of the market opportunity to the aftermarket, predominantly in applications for which removable disks provide a functional advantage. 5.25" and larger optical disk drives, however, have a stronger OEM base because of their use in automated libraries, their largest application area. Almost 74% of all Read/Write optical drive 1998 shipments were through the Distributor channel, with the 2002 Distributor share projected to decline moderately to about 63% of the worldwide total because of anticipated declining sales of 3.5" drives and a stronger market for higher capacity 5.25" drives.

The OEM/Integrator share of card format rigid disk drive shipments will be increasingly driven by manufacturers of specialized business and consumer systems, who make the buying decisions for removable storage products. As a result, the OEM channel is expected to become the major market for card format drives, rising from 37.4% in 1998 to a 69.3% share of 2002 unit shipments, based on the assumption that the manufacturers of digital cameras, PDAs, subnotebook computers and personal communicators will supply the storage device as part of the ultimate user's initial purchase.

TABLE 5

NONCAPTIVE WORLDWIDE REVENUES
OPTICAL AND REMOVABLE DISK DRIVES
PRODUCT GROUP REVIEW

REVENUE SUMMARY

WORLDWIDE REVENUES ALL MANUFACTURERS	1998 Revenues $M	1998 Revenues %	Forecast 1999 $M	1999 %	2000 $M	2000 %	2001 $M	2001 %	2002 $M	2002 %
CD-ROM OPTICAL DISK DRIVES	3,799.3 -16.4%	43.7%	3,199.5 -15.8%	34.2%	2,337.1 -27.0%	24.3%	1,491.1 -36.2%	14.6%	747.3 -49.9%	7.0%
DVD-ROM OPTICAL DISK DRIVES	461.0 +184.9%	5.3%	978.8 +112.3%	10.4%	1,532.8 +56.6%	15.9%	2,509.7 +63.7%	24.4%	3,370.9 +34.3%	31.9%
CD/DVD WRITABLE OPTICAL DISK DRIVES	1,148.5 +43.3%	13.2%	2,000.5 +74.2%	21.4%	2,493.3 +24.6%	25.9%	2,858.1 +14.6%	27.9%	3,039.0 +6.3%	28.7%
READ/WRITE OPTICAL DRIVES LESS THAN 4 GIGABYTES	579.0 +9.6%	6.6%	583.4 +.8%	6.2%	552.5 -5.3%	5.7%	452.0 -18.2%	4.4%	347.8 -23.1%	3.3%
READ/WRITE OPTICAL DRIVES MORE THAN 4 GIGABYTES	25.0 -22.8%	.3%	30.6 +22.4%	.3%	136.7 +346.7%	1.5%	377.3 +176.0%	3.6%	611.7 +62.1%	5.7%
RIGID CARTRIDGE DISK DRIVES	271.1 -21.7%	3.1%	180.6 -33.4%	1.9%	187.9 +4.0%	1.9%	210.5 +12.0%	2.1%	242.5 +15.2%	2.3%
CARD FORMAT RIGID DISK DRIVES	36.4 -28.1%	.4%	46.0 +26.4%	.5%	58.1 +26.3%	.6%	80.2 +38.0%	.8%	96.7 +20.6%	.9%
HIGH CAPACITY FLEXIBLE DISK DRIVES	846.4 +56.9%	9.7%	942.7 +11.4%	10.1%	1,029.6 +9.2%	10.7%	1,061.1 +3.1%	10.3%	1,063.9 +.3%	10.1%
LOW CAPACITY FLEXIBLE DISK DRIVES	1,548.9 +.3%	17.7%	1,418.6 -8.4%	15.0%	1,311.1 -7.6%	13.5%	1,234.2 -5.9%	11.9%	1,087.1 -11.9%	10.1%
Total Worldwide Revenues	8,715.6 +1.9%	100.0%	9,380.7 +7.6%	100.0%	9,639.1 +2.8%	100.0%	10,274.2 +6.6%	100.0%	10,606.9 +3.2%	100.0%

Note: Percentage figures with plus/minus signs refer to year-to-year growth rates.

TABLE 6

NONCAPTIVE WORLDWIDE SHIPMENTS
OPTICAL AND REMOVABLE DISK DRIVES
PRODUCT GROUP REVIEW

UNIT SHIPMENT SUMMARY

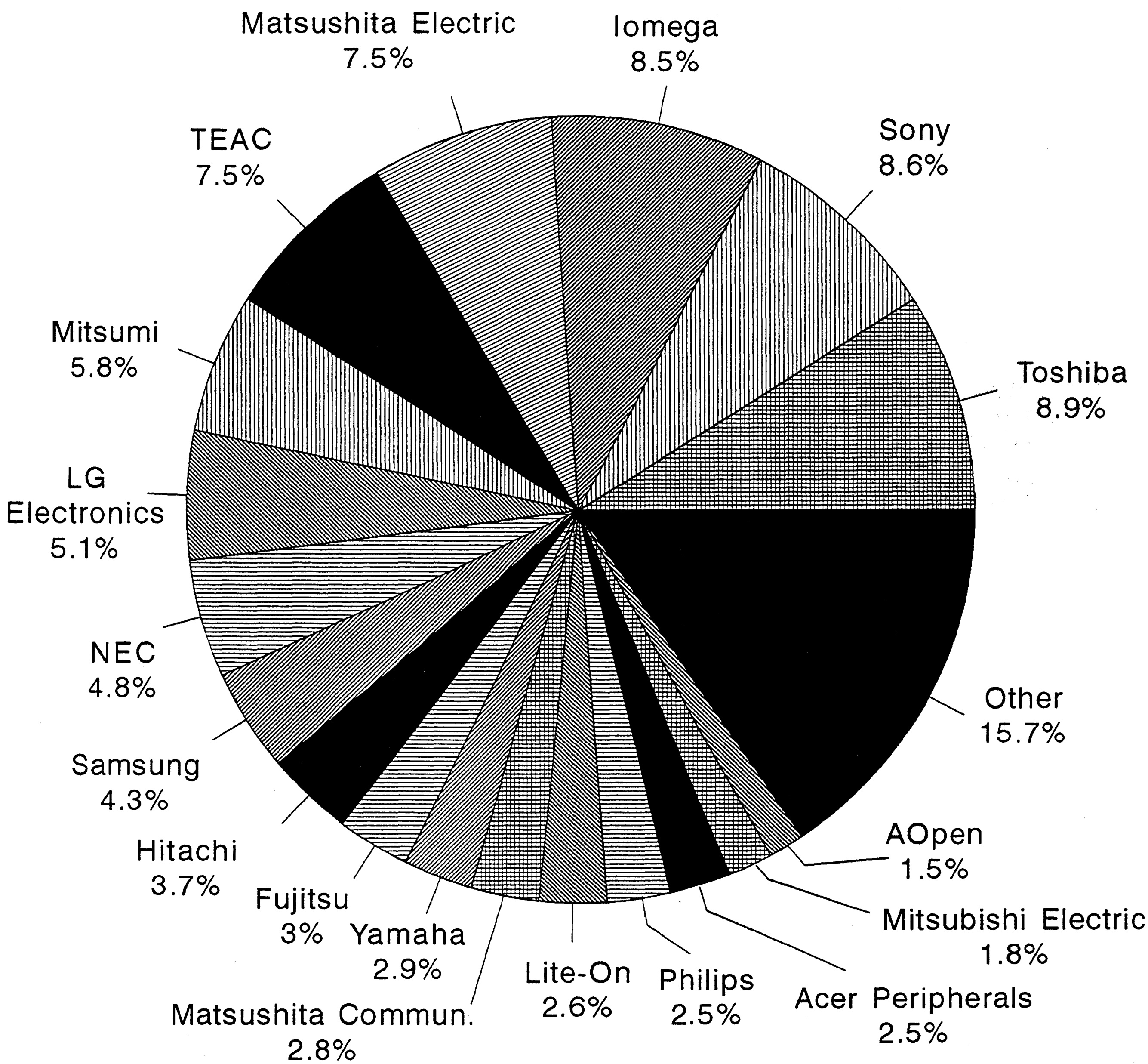
UNIT SHIPMENTS IN THOUSANDS	1998 Shipments Units	1998 Shipments %	Forecast 1999 Units	1999 %	Forecast 2000 Units	2000 %	Forecast 2001 Units	2001 %	Forecast 2002 Units	2002 %
CD-ROM OPTICAL DISK DRIVES	85,148.9 +23.5%	38.3%	88,841.0 +4.3%	35.3%	77,815.1 -12.4%	29.0%	54,233.0 -30.3%	19.3%	28,901.0 -46.7%	9.9%
DVD-ROM OPTICAL DISK DRIVES	4,460.4 +307.0%	2.0%	11,503.0 +157.9%	4.5%	25,649.0 +123.0%	9.5%	50,383.4 +96.4%	17.8%	78,005.8 +54.8%	26.9%
CD/DVD WRITABLE OPTICAL DISK DRIVES	5,672.7 +82.9%	2.5%	11,995.6 +111.5%	4.8%	18,074.4 +50.7%	6.7%	24,281.1 +34.3%	8.5%	28,536.6 +17.5%	9.7%
READ/WRITE OPTICAL DRIVES LESS THAN 4 GIGABYTES	1,769.5 +19.2%	.8%	1,931.8 +9.2%	.7%	1,871.0 -3.1%	.7%	1,574.2 -15.9%	.6%	1,312.8 -16.6%	.5%
READ/WRITE OPTICAL DRIVES MORE THAN 4 GIGABYTES	1.5 -34.8%	--	2.8 +86.7%	--	47.7 --	--	169.8 +256.0%	--	343.0 +102.0%	.1%
RIGID CARTRIDGE DISK DRIVES	1,289.7 -10.4%	.6%	970.0 -24.8%	.4%	1,120.0 +15.5%	.4%	1,410.0 +25.9%	.5%	1,820.0 +29.1%	.6%
CARD FORMAT RIGID DISK DRIVES	115.9 -42.9%	--	173.0 +49.3%	.1%	250.0 +44.5%	.1%	475.0 +90.0%	.2%	750.0 +57.9%	.3%
HIGH CAPACITY FLEXIBLE DISK DRIVES	12,756.0 +58.3%	5.7%	18,740.0 +46.9%	7.4%	24,230.0 +29.3%	9.0%	29,700.0 +22.6%	10.5%	34,130.0 +14.9%	11.7%
LOW CAPACITY FLEXIBLE DISK DRIVES	111,926.0 +17.6%	50.1%	118,512.0 +5.9%	46.8%	120,614.0 +1.8%	44.6%	120,880.0 +.2%	42.6%	117,810.0 -2.5%	40.3%
Total Worldwide Shipments	223,140.6 +24.3%	100.0%	252,669.2 +13.2%	100.0%	269,671.2 +6.7%	100.0%	283,106.5 +5.0%	100.0%	291,609.2 +3.0%	100.0%
% U.S. Manufacturers	4.8%		5.4%		6.2%		6.9%		7.4%	

Note: Percentage figures with plus/minus signs refer to year-to-year growth rates.

Figure 2

1998 ESTIMATED MARKET SHARE

Optical and Removable Disk Drive Worldwide Revenue



1998 Revenue: $9,658,700,000

TABLE 7

1998 ESTIMATED MARKET SHARES

WORLDWIDE REVENUES OF ALL OPTICAL AND REMOVABLE DISK DRIVES
(Value of non-U.S. currencies estimated at average 1998 rates)

	CAPTIVE		DISTRIBUTOR		OEM/INTEGRATOR		TOTAL INDUSTRY	
	$M	%	$M	%	$M	%	$M	%
U.S. MANUFACTURERS								
Iomega	--	--	469.3	12.6	347.3	7.0	816.6	8.5
Other U.S.	--	--	101.8	2.7	16.3	.3	118.1	1.2
U.S. Total	--	--	571.1	15.3	363.6	7.3	934.7	9.7
NON-U.S. MANUFACTURERS								
Acer Peripherals	48.4	5.1	111.8	3.0	77.6	1.6	237.8	2.5
Alps Electric	--	--	37.4	1.0	70.3	1.4	107.7	1.1
AOpen	--	--	58.2	1.6	86.2	1.7	144.4	1.5
Behavior Tech Computer	--	--	82.5	2.2	44.9	.9	127.4	1.3
Fujitsu	16.3	1.7	252.0	6.8	21.1	.4	289.4	3.0
Hitachi	.4	--	110.1	3.0	245.3	4.9	355.8	3.7
LG Electronics	6.8	.7	195.1	5.2	293.7	5.9	495.6	5.1
Lite-On	--	--	83.2	2.2	165.0	3.3	248.2	2.6
Matsushita Communications Ind.	--	--	108.5	2.9	157.4	3.2	265.9	2.8
Matsushita Electric Ind.	150.8	16.0	157.9	4.2	412.5	8.3	721.2	7.5
Mitsubishi Electric	2.1	.2	37.1	1.0	136.2	2.7	175.4	1.8
Mitsumi Electric	--	--	307.7	8.3	251.7	5.0	559.4	5.8
NEC	123.4	13.1	142.2	3.8	194.1	3.9	459.7	4.8
Olympus Optical	--	--	63.7	1.7	52.0	1.0	115.7	1.2
Pan-International (Cyberdrive)	--	--	25.8	.7	88.3	1.8	114.1	1.2
Philips	--	--	66.5	1.8	176.8	3.5	243.3	2.5
Pioneer Electronic	--	--	104.0	2.8	34.8	.7	138.8	1.4
Samsung Electronics	48.6	5.2	209.2	5.6	156.4	3.1	414.2	4.3
Sony	88.1	9.3	151.5	4.1	595.7	11.9	835.3	8.6
TEAC	--	--	188.8	5.1	538.4	10.8	727.2	7.5
Toshiba	447.2	47.4	103.5	2.8	307.1	6.2	857.8	8.9
Yamaha	--	--	145.0	3.9	133.9	2.7	278.9	2.9
Other Non-U.S.	11.0	1.3	415.1	11.0	384.7	7.8	810.8	8.3
Non-U.S. Total	943.1	100.0	3,156.8	84.7	4,624.1	92.7	8,724.0	90.3
WORLDWIDE TOTAL	943.1	100.0	3,727.9	100.0	4,987.7	100.0	9,658.7	100.0

Note: The DISK/TREND estimates of revenue for each manufacturer include net sales of removable data storage products only and do not represent total revenues for individual companies

Codes: 1 = 1" C = Captive
1.8 = 1.8" D = Distributor
2 = 2.5" 0 = OEM
3 = 3.5"
4 = 4.72"
5 = 5.25"
8 = 8"
12 = 12"

TABLE 8

CURRENT PRODUCT LINES
MANUFACTURERS OF OPTICAL AND REMOVABLE DISK DRIVES

DISK/TREND PRODUCT GROUP	Type	20 CD-ROM Optical Disk Drives	21 DVD-ROM Optical Disk Drives	22 CD/DVD Format Writable Disk Drives	23 Read/ Write Disk Drives <4 GB	24 Read/ Write Disk Drives >4 GB	1 Removable Disk Cartridge Drives	2 PC Card Rigid Disk Drives	13 High Capacity Flexible Disk Drives	14 Low Capacity Flexible Disk Drives
U.S. Manufacturers (13)										
Caleb Technology	D,0								3	
Castlewood Systems	D,0						3			
Digital Video Systems	D,0		4							
Hewlett-Packard	C,D,0			4						
IBM	D,0							1		
Imation	D,0								3	
Iomega	D,0						3		1.8,3	
Halo Data Devices	D,0							1		
Maxoptix	D,0				5					
Mountain Optech	0	4			5					
PCS, Inc.	0							1.8		
Pinnacle Micro	D,0				5					
TeraStor	D,0					5				
Asian Manufacturers (44)										
Acer Peripherals	D,0	4	4	4						
Actima	D,0	4	4	4						
Afreey	D,0	4	4							
Alps Electric	D,0								3	3
AOpen	D,0	4	4	4						
Asustek Computer	D,0	4								
Behavior Tech	D,0	4	4	4						
Citizen Watch	0									3
Delta Electronics	D,0	4		4						
EPO Technologies	D	4								
Fujitsu	C,D,0				3					
Hitachi	C,D,0	4	4	4	5					
JVC	D,0			4						
Kenwood	D,0	4								
Konica	D,0				3					
Leoptics	D,0	4	4	4						
LG Electronics	C,D,0	4	4	4						
Lite-On Technology	D,0	4	4	4						
Matsushita Commun. Ind.	D,0								3	3
Matsushita Electric Ind.	C,D,0	4	4	4						
Matsushita Kotobuki Elect.	D,0	4	4	4					3	
Mitsubishi Electric	D,0								3	3

TABLE 8 (Continued)

DISK/TREND PRODUCT GROUP	Type	20 CD-ROM Optical Disk Drives	21 DVD-ROM Optical Disk Drives	22 CD/DVD Format Writable Disk Drives	23 Read/ Write Disk Drives <4 GB	24 Read/ Write Disk Drives >4 GB	1 Removable Disk Cartridge Drives	2 PC Card Rigid Disk Drives	13 High Capacity Flexible Disk Drives	14 Low Capacity Flexible Disk Drives
Asian manufacturers (continued)										
Mitsumi Electric	D,O	4		4						3
Nakamichi	D,O	4								
NEC	C,D,O			4	5				3	3
NEC Home Electronics	C,O	4								
Olympus	D,O				3					
O.R. Technology	D,O								3	
Pan-International	D,O	4	4	4						
Pioneer	D,O	4	4	4	5					
Plextor (Shinano Kenshi)	D,O	4		4						
Raite Optoelectronics	D,O		4							
Ricoh	D,O			4						
Samsung Electronics	D,O	4	4	4						
Samsung Electro-Mechanics	D,O								3	3
Sanyo Electric	D,O	4		4						
Sony	D,O	4	4	4	5				3	3
Tatung	D,O	4	4	4						
TEAC	D,O	4	4	4					3	3
Toshiba	C,D,O	4	4	4						
Ultima Electronics (Artec)	D,O	4		4						
Wearnes Peripherals	D,O	4		4						
Yamaha	D,O			4						
Y-E Data	O									3,5,8
European Manufacturers (4)										
Calluna Technology	D,O							1.8		
New ATG	D,O					12				
Philips	D,O	4	4	4						
Plasmon LMS	D,O					12				

TECHNICAL REVIEW

This section briefly reviews the status and significant technology trends for optical and removable disk drives in the following areas:

- CD-ROM and DVD-ROM disk drives
- CD and DVD writable disk drives
- Read/Write optical disk drives other than CD/DVD formats
- Card format rigid disk drives
- Rigid disk cartridge drives
- High capacity flexible disk drives
- Low capacity flexible disk drives

Optical disk drive technology and applications

Three types of optical disk drives used as computer peripheral devices are discussed in the following sections: CD format (usually 120 mm) read-only disk drives (including CD-ROM and DVD-ROM), write-once disk drives (including CD-R, and DVD-R), and rewritable disk drives (including MO drives, phase change drives, CD-RW, DVD+RW, DVD-RAM and other DVD writable drives). Some rewritable drives, such as CD-RW and MO, can also record on write-once media compatible with that specific drive type.

- CD format read-only disk drives: In optical read-only recording, the disk is normally mass produced using a mold which impresses the data upon one or more surfaces of the disk, followed by the deposition of a metal layer and a protective layer to establish the proper reflectivity. When scanned by a laser beam, the reflected beam is modulated by the data pattern on the disk, and the signal pattern is processed within the drive. Processing includes error correction and may also include decompression if audio or video data is present.

  Mass production of read-only optical disks is done by a mastering and mass replication process, rather than by recording directly on the disk, so cost per disk is low, usually under a dollar per disk. However, mastering costs and replication turnaround time can make production of single disks or very short runs economically unattractive, a factor that encourages the use of CD-R or CD-RW drives for use in short run production, rather than CD-ROM. DVD disks require a few additional process steps and more complex equipment to accommodate dual layer media, but single layer media replication costs are increased only moderately by the DVD format. Yield is still a problem for multilayer replication.

Except for CD/DVD format disk drives, (and laser videodisks, not covered in this report) optical read-only (OROM) solutions have not met with success. Read-only memory formats were proposed for 3.5" and 5.25" and 12" media, but were rejected by the industry due to high media costs inappropriate for a distribution medium. CD-ROM acceptance benefited from early industry agreement on the CD and CD-ROM standards developed jointly by Sony and Philips and also from the recording format standard for computer data formalized as ISO standard 9660. Some media manufacturers, most recently Eastman Kodak, have promoted hybrid media with a pressed read-only portion and a writable portion, but so far these have appealed only in niche applications (such as the Kodak Photo CD program) and have not yet found broad acceptance.

12 centimeter diameter CD format drives (CD-ROM and DVD-ROM), which have typical on-line capacities of 550 megabytes to 8.5 gigabytes depending upon the format and media used, are now the dominant form of read-only optical memory. These drives typically read 8 centimeter media as well, but the 8 centimeter format is not widely used. The few manufacturers attempting to launch an 8 centimeter CD-ROM drive (capable of storing only 180 to 200 megabytes of data) have had only limited success to date.

Most CD format drives are equipped with IDE/ATAPI interfaces and sold to computer manufacturers, although drives are also made with SCSI interfaces for use with servers, optical libraries, CD format disk towers or computers supporting SCSI interfaces. A few recent drives are equipped with UltraSCSI. Drives with the USB interface are becoming popular in the aftermarket for attachment to notebook computers and the Apple iMac. Some drives are equipped with PC Card interfaces to permit them to be easily connected to notebook computers with PC Card slots.

An increasing number of CD-ROM titles now require more than one disk to hold all of the content, and motion picture storage requires 4 to 5 gigabytes to store a typical movie. Movie video requires a data transfer rate in excess of 3 megabytes per second. This need is addressed by DVD-ROM, which offers 4.7 gigabytes per surface and can also read CD format media. As prices decline, DVD-ROM is now beginning to displace CD-ROM. Multi-surface DVD-ROM offers 8.5 gigabytes per side of on-line capacity, taking advantage of the drive's capability to adjust the focal plane of the reading head optics to address multiple surfaces.

The DVD format arose from the combination of two contending specifications for drives in the multiple gigabyte range. General agreement was reached in late 1995 for a combined standard. The Multi Media CD (MMCD) format, proposed by Sony and Philips, and the Super Density (SD) format, sponsored by Toshiba and Matsushita were blended to reach a joint specification, avoiding a format war, although issues of backward compatibility with CD-R drives continued to plague DVD-ROM drives for several years. Forward compatibility with writable DVD format drives is still an issue.

DVD drives use shorter wavelength lasers (630 to 650 nanometer), rather than the 780 nanometer lasers used for CD-ROMs, providing smaller spot size and higher areal density and data transfer rates. First generation DVD drives provided approximately 9 times (9X) the data rate of the first CD-ROM drives, but not low average access times. The 1X DVD data transfer rate, about 1.35 megabytes/second, was inferior to CD-ROM rates for 12X drives and faster. DVD-ROM manufacturers quickly initiated the same speed race that caused massive product instability in the CD-ROM market, moving through 2X, 4X, 5X, 6X to the current 8X drive capabilities. Most manufacturers expect a move to 16X within a year, though technical difficulties may slow or halt the speed race at that point.

Disagreement between major suppliers and between suppliers and content providers on specifications, standards and copy protection delayed availability of DVD-ROM, DVD-R and DVD-RAM, although it appeared that general agreement on copy protection and related restrictions desired by the entertainment and software industries had been reached as of mid-1997.

The high production volumes achieved by CD-ROM drive manufacturers have made possible steep cost reductions, while the demands of computer manufacturers for faster drives have stimulated performance improvements. During the last year, CD-ROM drives from the majority of drive manufacturers went to 40X in data transfer rate in order to improve output, and it appears that there has been OEM acceptance of 48X drives, despite the probability that their use may actually degrade performance if marginally replicated media is in use. 50X and 56X drives are being shipped, but primarily to the aftermarket. For the 6,000 to 10,000 RPM range reached by the faster drives, noise and vibration become objectionable to users and create reliability problems.

At 32X and above, the industry speed race in CD-ROM is well past the point of diminishing utility to the user. Although fast data transfer rates can help reduce the time required to install software, at only 8X sustained data rates, a 10 megabit per second local area network will be saturated. 20-24X data transfer rates can saturate many processors. Other than games, most applications don't require even 8X performance, but computer manufacturers eager to improve system specifications have created early demand for ever-faster CD-ROM drives. Average access times have dipped below 90 milliseconds for some models, although most DVD-ROM drives still exceed 100 milliseconds.

CD-ROM is now a preferred medium for distributing system documentation and software as well as sizable application packages. Industry efforts to convince software manufacturers to distribute on DVD media have had only limited success because of the relatively small installed base of DVD-ROM drives.

DVD-ROM capacities will increase as shorter wavelength semiconductor lasers enter production and fall to reasonable price levels. At present, it seems reasonable to expect that the capability to produce a higher capacity version will appear within the next few years.

- Write-once disks: The first optical disk recording systems to enter the market were "nonreversible" or "write-once" systems. A few systems with optical drives were sold in Japan in 1984, but it wasn't until 1986, after many years of costly development programs undertaken by manufacturers, that such devices began to move into production status.

  Write-once recording usually involves changing the reflectivity of an area of the disk, either by making a small hole or causing a surface reflectance change. Recording systems are available which alter the writing layer from an amorphous to a crystalline state, while others alter the recording layer of the media to cause a reflectance change at the point where a bit is written. More recently developed write-once technology (known as Continuous Composite WORM, or CCW, or MO-WORM) uses magneto-optic media, which is normally rewritable, prestamped with information indicating that it is to be used only in a write-once mode. With the recent success of CD-R format write-once recording, media incorporating an organic dye layer (cyanine or pthalocyanine) that absorbs the laser beam energy, changing its state and creating a mark, has become the dominant form of write-once media.

  Writing power required at the surface of the disk is in the range of 10 milliwatts, for writing at useful rotation rates of the disk media. Losses in the optical subsystem of the head require a laser with emitted power in the range of 20 to 30 milliwatts. Higher rotation rates require higher power lasers. Read power is typically in the 1.5 to 2 milliwatt range, but must be carefully controlled to avoid an inadvertent write, due to the cumulative effects of successive read operations. To achieve media interchange, disk drives must be able to sense the media formulation in use and adjust power levels.

  Write-once drives require more complex logic to operate with computer operating systems which expect a disk drive to be rewritable, adding to system complexity and cost. Write-once storage also requires more user management than rewritable storage once the disks become completely written. Long latency, slow head positioning, read verification cycles and slow data transfer rates also make write-once storage a poor performer compared to magnetic disk drives. However, fast rewritable optical disk drives using CCW media can provide some improvement in write-once performance, and the low cost of CD-R media make it a popular choice for archiving and backup, provided that the write rate performance of such drives (now reaching 1.2 megabytes per second) is acceptable.

Extensive accelerated testing indicates that write-once disks should provide archival lives which equal or exceed those of magnetic tape, with 10 years being the minimum specification for archival life of the media. Some media suppliers specify a 30 year lifetime and claims of lifetimes exceeding 50 years have been made. Ablative write-once media is typically based on tellurium films. Media based on dye or dye-polymer designs have no metallic films and are less expensive and more corrosion resistant than the original generation of metallic films. Other optical media using platinum or tin alloys as recording layers offer corrosion resistance, but trade off write sensitivity for the improved longevity obtained, requiring more powerful lasers.

Applications for write-once recording technology, including CD-R, include distribution of data, backup and the archival storage of documents and data. A document is often stored as a document image, rather than as character data, sometimes using 12" disks housed in automated optical libraries. CD-R is also used for preparing CD format master disks for subsequent replication. Increasing integration of CD-R electronics into fewer chips has reduced the price of CD-R drives to well below the $200 level and the low cost of CD-R media makes them popular devices for data distribution, archiving and backup. However, pure CD-R drives are being phased out in favor of CD-RW drives that can read and write inexpensive CD-R media as well as the more expensive rewritable media.

While the market for write-once optical storage is limited to niche markets that can tolerate nonreversibility, the ability of write-once storage to maintain an audit trail or indicate whether or not stored data has been modified is a benefit in applications requiring a high integrity audit trail.

- Rewritable optical disks: Magneto-optic (MO) recording, whose roots go back over 35 years, was the first optical rewritable technology to achieve commercial success, but rewritable phase change alloys in use for CD-RW and DVD-writable drives are now the most widely used rewritable optical technology. Dye based materials can also exhibit rewritability, but no such material has yet been developed to the point where it can compete with MO or phase change recording.

  Current magneto-optic drive designs use a low power laser to change the magnetic state of the active layer on a disk. The laser raises the temperature of the active layer into the range of the Curie point while a magnetic field is present, causing individual magnetic domains on the disk to align with the direction of the external magnetic field. Changes in magnetic orientation are detected during reading, as the affected spot on the disk causes a small rotation in the polarized light reflected from the surface or transmitted through the disk. Because the polarization shift is small, it is harder to get adequate signal to noise ratios with MO media than it is with other types of media.

Magneto-optic media require less laser power for writing than phase change or dye-based media because there is no need to physically deform the writing layer or cause it to melt, permitting the disk to rotate faster for a given available laser power. The faster rotation improves latency and data transfer rate. Recently produced magneto-optical disks employ light intensity modulation (LIM-DOW) to provide direct overwrite in place, avoiding the requirement that a complete sector must be erased before the sector can be rewritten.

Phase change optical recording involves a different type of amorphous coating, in which individual spots on the disk are changed by laser irradiation from a crystalline state, during which light is reflected, to a noncrystalline state, during which light is absorbed. Alternatively, different crystalline states are used to vary reflectivity. Media stability over long periods of time, excessive phase reversal time, and a limited number of possible write/erase cycles still represent problem areas for rewritable phase change technology. However, if the price is competitive with tape technology, phase change media having a write/erase cycle capability of at least 1,000 cycles can compete for backup and other applications where infinite rewritability is not required. Matsushita Electric is shipping phase change drives and media with over 100,000 write cycle capability, so this segment of the market is within the grasp of the technology. Phase change media also has the advantage of offering direct overwrite, a current limitation for some MO drives and media, and thus can be faster than magneto-optic drives in write mode. The drive does not require the bias magnet typically used in MO drives. Phase change recording is used for CD-RW and writable DVD drives, although MO has also been suggested as an alternative to DVD-RAM with performance characteristics more suited to computer requirements.

Variable packet writing now permits CD-R and CD-RW drives to appear to computing systems as a standard disk drive. Unfortunately, the format war that broke out in 1997 between supporters of various writable DVD formats shows no sign of being settled soon. As has been the custom in the optical segment of the storage industry, writable DVD format optical drive purchasers will soon have a variety of format "standards" from which to choose.

Other proposed reversible optical recording technologies are known, but none of these have overcome all of the problems, that have included: Slow reversal cycle, limitations on the number of reversals before degradation, poor shelf life, and low recording density.

The first 12" rewritable drive, with 2 gigabytes per side, was announced by Nikon in late 1991, but most manufacturers, including Sony, Fujitsu, IBM, NEC, Hitachi, Maxoptix, Hewlett-Packard and others, concentrated on 5.25" and 3.5" drives. 5.25" drives and media with 1.3 gigabytes per side became available in late 1995 and early 1996, with MOST the first company to formally announce such a drive. 2.6 gigabyte per side drives were announced in late 1997 and early 1998, with 1998 availability. Drives with 4.55 gigabytes per side have been announced by Sony for delivery in 2000. 3.5" drives, introduced originally at 128 megabyte capacity, subsequently were introduced at 230 and 640 megabyte capacity points. 1.3 gigabyte drives are set for late 1999 delivery.

1999 may yet see the first availability of new families of magneto-optic drives offering projected capacities of 6 to 20 gigabytes per side on 4.72" or 5.25" media. These are expected to offer only limited compatibility with earlier drives.

A consortium of drive and media manufacturers is investigating the possibility of producing MO disk drives in a 12 centimeter form factor, with the drive able to make use of CD format drive components to reduce cost. Capacity on a single surface is expected to be 6 gigabytes, achieved by using PRML encoding and super-resolution optical recording technology, which involves writing with a flying magnetic head while the laser illuminates the recording layer. The drive would also be able to read CD-ROM and DVD disks. The project is considered difficult, with no product available currently. Drive and media specifications were produced in mid-1997 by companies supporting the ASMO development effort, including Fujitsu, Sanyo, Olympus, Hitachi, Sharp, Sony and several media manufacturers.

Card format rigid disk drive technology

PC Card and CompactFlash Card formats were each originally developed for use with flash memory and other electronic products, and both have been utilized with miniaturized rigid disk drives. Version 2.1 of the PCMCIA specification covers peripheral devices, including rigid disk drives mounted in PC Cards, and many 1.8" disk drives produced during the 1990's have used the PC Card Type III format, 10.5 millimeters high, for several years, and a new Calluna Technology drive will use the PC Card Type II format, 5 millimeters high. The CompactFlash Association approved the smaller CF Type II format, 5 millimeters high, in March, 1998, and it will be used for IBM's new 1" microdrive. The startup company Halo Data Devices plans to use the original CF Type I format, 3.3 millimeters high, for its 1" single head drive.

The PC Card 1.8" rigid disk drives available for several years have been used for a variety of specialized mobile applications, but the market size has been held down by the limited storage capacity available and price per megabyte levels much higher than available with larger rigid disk drives, such as 2.5" models. The outlook for the current generation is more promising, when the higher capacities now being offered in the PC Card format are considered, along with the smaller package provided for 1" drives by the CompactFlash formats. The major challenges confronting designers of the next generations of these drives will be to adapt the continuing advances in magnetic disk drive areal density to these miniature formats, and to find ways to squeeze manufacturing costs to the lowest possible level.

- Areal Density: The most significant aspect of rigid disk drive technology is the trend line of areal density (TPI x BPI) increase. The rigid disk drive industry is currently increasing recording density at an average rate of 60% or more annually, and this rate is expected to be maintained through 2002. It is this inexorable improvement that will keep the cost per megabyte of rigid disk storage well below the cost of nearly all other memory technologies (except tape) during the remainder of the decade. The highest 1.8" drive areal density available as of mid 1999, found in the Calluna 1,040 megabyte drive, is 1.5 gigabits per square inch. This is a fraction of the areal densities already being utilized on larger fixed disk drives, and a conservative level allowing for continued improvements. IBM's microdrive 1" disks use an areal density of 5 gigabits per square inch, but this is just the starting point. As areal densities increase rapidly during the next few years, IBM's published development roadmap indicates an expected increase in drive capacity for the microdrive from today's 340 megabytes to more than 1 gigabyte.

- Power requirements: Rigid drives require more power than semiconductor memories when operating, so power reduction and on-board power management are critical functions and likely to remain so.

- Interface: The PC Card disk drives conform to PCMCIA Release 2 physical specifications and use the PCMCIA 68 pin connector rather than the standard ATA 40 pin connector. The PCMCIA-ATA card also supports extended I/O addressing, necessary for removable drives, and supplies CIS data to the host on request. PCMCIA-ATA drives can support either 8 bit or 16 bit data transfers, as compared to the ATA 8 bit transfer only. Host resident drivers for ATA drives must be revised to account for the removability of the PCMCIA-ATA drives and other features. Such drivers are labeled as "PCMCIA-aware". The CompactFlash Association approved the "CF+" specification in October, 1998, adding a variety of features to the CF basic specification, supporting magnetic disk drives and other devices.

- Shock resistance: Because they have moving parts, card format rigid disk drives are more vulnerable to mechanical disturbances than their all-electronic counterparts. When removed from the host system, card mounted drives are more susceptible to shock damage, so nonoperating shock damage elimination is also critical for card format rigid disk drives.

  Considerable insensitivity to the effects of operating shock has been obtained by incorporating piezoelectric shock sensors into the drive and halting writing operations when an excessive shock is detected, eliminating the possibility of off track or adjacent track writing that can cause unrecoverable errors. The 1 inch diameter drives will have improved shock resistance because their components have lower mass and inertia and are easier to restrain from undesired movement. Dynamic head loading, used by Integral Peripherals and in the IBM microdrive, help reduce nonoperating shock damage because the heads are parked off the disk when the drive isn't operating.

- Performance: Today's 1.8" drives have average access times in the 18 to 22 millisecond range, substantially inferior to flash memory cards. Startup time is in the 1-2 second range, also slow compared to flash memory. Media data transfer rates are in the 3 to 6 megabytes per second range, with burst rates up to 20 megabytes per second. Media data transfer rates will probably increase as linear densities increase.

- Electronics: Drive servos are shifting to use of digital signal processing in servo tracking subsystems as TPI increases put more strain on tracking tolerances. Channel electronics are becoming more complex in order to accommodate the higher data transfer rates associated with higher linear density. While these improvements assist performance and help improve capacity, they also add cost and power consumption, both undesirable attributes for portable systems.

- Motors: It is necessary for drive motor designers to be very creative to accommodate the ever-decreasing drive heights, especially for those incorporated into 1 inch drives, which must fit within a 5 millimeter height. Actuator designs are also being stressed for the same reason, and for some very thin drives, maintaining the expected performance levels will be a challenge.

- Competing technology: Flash memory is the major challenge to Card format rigid disk drives, offering superior survival in difficult environments and low power consumption. However, flash memory is expensive. At the current $4 per megabyte OEM price of flash memory, rigid disk drives offer lower cost and faster write performance where capacity over 100 megabytes is required.

Magnetic rigid disk cartridge drive technology

Disk cartridge drives are currently available in the 3.5" form factor. SyQuest's attempt to market a 1.8" drive in the PC Card form factor was not successful because of cost and technical problems, and the drive's 80 megabyte capacity limited potential industry acceptance. Avatar's attempt to market a 2.5" cartridge drive was similarly unsuccessful.

All of the factors that apply to rigid disk drives in general pertain to cartridge drives, but the need to accommodate removable cartridges makes it difficult to match the areal densities achieved by drives with sealed head/disk assemblies. Disk cartridge drives must also be designed to deal with dust and airborne chemical pollutants to a degree not required of sealed HDA designs. And competitive pressures make it imperative for cartridge drive producers to use single disk cartridges.

Driven by competition from optical disk drives and high capacity flexible disk drives, and able to draw upon basic improvements in magnetic drive technology, rigid disk cartridge drive technology has improved dramatically in the past few years. Industry direction for nonspecialized markets has shifted to smaller form factors, with 2 gigabytes now available on Iomega's 3.5" Jaz 2 drive and the Castlewood ORB. Larger capacities in the smaller form factors are expected to become available as areal densities increase. Disk cartridge drives will be able to take advantage of the heads, disks, motors and semiconductors developed for the much larger market provided by fixed disk drives. The special operating environment of removable disk cartridge drives will require improved filtration systems and cartridge protection systems to eliminate airborne pollutants, all attainable refinements of existing technologies.

The primary applications for disk cartridge drives have been data interchange associated with graphics, video, and desktop publishing, plus secure system data storage, where they compete with PC Card rigid drives, small optical drives, high capacity flexible drives, and, in nongraphics applications, with flash memory, as flash capacity increases. Compared to the competition, rigid disk cartridge drives can offer cost advantages, and frequently provide more capacity and ease of use. The major technology challenge for disk cartridge drives, as always, is to improve reliability, a difficult assignment due to the lack of a completely closed head/disk assembly. Most users currently regard disk cartridge drive reliability as adequate, but it will be necessary to continue to improve, as competition increases from other data storage products.

High capacity flexible disk drive technology

Flexible disk drives in this group use a variety of technologies to provide capacities above those offered by standard floppy drives, including the 40 megabyte Clik! and 100/250 megabyte 3.5" "Zip" drives from Iomega, the 3.5" 120 megabyte "floptical drives" initially introduced by Insite Peripherals and now manufactured by Matsushita-Kotobuki Electronics and others, the Sony HiFD 200 megabyte drive, the Samsung Electro-Mechanics 123 megabyte drive, and the Caleb 144 megabyte drive. Because of the relatively high prices of these drives compared to standard floppy drives, they compete with rigid magnetic disk drives, optical disk drives and tape drives, for specialized markets which need recording devices with removable media. It is a difficult environment, however, with extremely competitive prices for the alternative products.

Originally introduced in an 8" diameter format, the Iomega Bernoulli Box (now phased out) transitioned to a 5.25" format and was available in capacities up to 230 megabytes. Performance was competitive, with average seek times in the 20-25 millisecond range. The performance of high capacity 3.5" drives in this group can approach that of the Bernoulli drives, and is better than that of standard 1.44 megabyte floppy drives. Typical high capacity 3.5" floppy drives are one inch high, but thinner drives entered the market in the second half of 1997. Individual design approaches used to create high capacity 3.5" flexible drives are generally not compatible with each other.

Thin motors suitable for inclusion in high capacity floppy drives intended for notebook computers are still a problem for the industry, but it appears that adequate supplies of motors permitting the manufacture of 12.7 millimeter high drives are now available.

- Rigid drive technology: The Iomega "Zip" drive borrows head and semiconductor technology from the rigid drive industry, obtaining design simplicity, low parts count and reduced costs as a result of being able to use components similar to those already being produced in volume for the rigid drive industry. Iomega's success has inspired other competitors to adopt a similar philosophy in their high capacity flexible disk drive design efforts.

- Tracking systems: Developed by Insite Peripherals, the original 20 megabyte floptical drives used optical tracking to provide 1,245 TPI and 1,7 RLL coding to reach almost 24,000 BPI. The barium ferrite media was packaged in a standard 3.5" floppy disk shell. To provide a tracking servo signal, the media was laser branded with a pattern of concentric rings. A multisensor pickup device received reflected light and generated appropriate tracking data. As manufactured in recent years, track density of the floptical drives was 1,245 TPI, but improved optics, the use of metal powder media and tighter track spacing have increased the available capacity several times. The second generation floptical technology drive, renamed the LS-120, and later called SuperDisk, with 120 megabyte capacity has 2,490 TPI and 44,880 BPI, also using 1,7 RLL coding. Because it has two heads, the new drive is backward compatible with standard 3.5" floppy drives, but its initial high production cost (resulting from the need to support dual read/write channels and the optical tracking system) has made cost reduction imperative for the companies supporting the format. All of the other current high capacity formats employ embedded servo techniques, in which servo track information is written on each removable disk. Each drive is able to determine head position with the same standard magnetic heads used to read and write data.

- Metal powder media: Using metal powder media and conventional recording techniques, several Japanese firms, including NEC, Matsushita Communication Industrial and Y-E Data, introduced 3.5" floppy drives from time to time with capacities up to 20 megabytes (NEC introduced a 10 megabyte version in 1990). However, all were withdrawn from the market due to limited acceptance of their limited capacity. Proponents of the metal powder approach have long claimed that it can support floppy drive capacities of 200 megabytes or more using standard form factor flexible disks, and recent history supports this claim. The Iomega "Zip" drive achieves up to 250 megabyte capacity with metal powder media, as does the 120 megabyte LS-120 drive and drives from others still in development. Metal powder media is expected to be able to support significant increases in disk capacities.

- Other methods: Various manufacturers have examined the possibility of increasing the capacity of standard floppy drive media by a judicious choice of coding, modulation scheme or compression without changing the fundamental file structure of the drive. While such methods can produce higher capacities, it is questionable whether the limited increase in storage capacity warrants the industry-wide standardization effort required to gain acceptance for any given method or combination of methods.

- Competing technology: Flash memory is the primary competition for the 40 megabyte Iomega Clik! drive, while the higher capacity drives in this product group compete to some degree with CD-RW drives. However, the primary competition for any drive in this group is other drives in the same group, with the competition between multiple formats a significant obstacle to displacement of other types of storage.

Low capacity flexible disk drive technology

There has been little recent, significant change in low capacity floppy drive technology. Notebook computers use large numbers of half inch high 3.5" drives, but one inch high 3.5" drives are still the standard for desktop computers. 2.88 megabyte 3.5" drives, once standard on many IBM PS/2 personal computers, were phased out, having generated limited market response among IBM's customers. The most significant technical development efforts are now aimed at high capacity drives.

Low capacity floppy drive development has slowed, but other technologies competing as a universal distribution medium remain too costly, too slow, or are not standardized for universal data interchange. Standard 3.5" flexible disk drives have succeeded because they offer low cost, recordability, random access, interchange standards and media removability. CD-ROM drives, now a standard for software distribution, are limited to the distribution role, due to the lack of recording capability. A critical problem for competitors is that any alternate technology must offer significant improvements at a competitive price, and the 1999 OEM price for 3.5" floppy drives is in the $11 range.

Ever-smaller form factors, higher capacities, more effective designs, the need to read existing libraries of disks, and lower cost manufacturing methods have sustained floppy drive cost-effectiveness against competitive data storage technologies. Consequently, alternate technologies find only limited success in breaking into floppies' established markets, although some displacement of floppy drives is occurring in notebook and handheld computers where there is insufficient space or power for floppy drives. The most likely successor to the low capacity floppy disk drive is a high capacity floppy disk drive, although prices will have to decline greatly to produce a large-scale displacement.

Aside from cost reduction efforts, developments in low capacity floppy technology seem limited to a few areas:

- Form factor: Half inch high 3.5" floppy drives now in production permit designers of notebook computers to reduce weight and system size, and to match the heights of 12.7 millimeter high 2.5" rigid disk drives. Nominal half inch high floppy drives now offered in formats from 11 to 12.7 millimeters in height are widely used in notebook computers. They have also found usage in subsystems which combine a 3.5" floppy drive with a CD-ROM drive in a single unit designed to be used in a single slot in desktop or notebook systems.

  Low capacity floppy disk drives have evolved from 8" disk drives through 5.25" disk drives to 3.5" disk drives, but the prospects for further diameter shrinkage in the low capacity category seem unlikely. Attempts to reduce diameter to 2.5" or less go back to the late eighties and a few drives were actually introduced, but the computer industry has not found it economically attractive to go through one more stage of diameter shrinkage.

- Media: The polyester substrate used with flexible disks suffers from limitations in its dimensional stability which derive from the manufacturing process used. As a result, today's mainstream floppy drive products using open loop head positioning systems for low cost are limited to 48 TPI with 8" drives, 96 TPI with 5.25" drives, and 135 TPI with 3.5" drives.

  Some substrate materials do offer high stability and resistance to environmental degradation, but are very expensive relative to polyester films and are unlikely to be widely adopted.

DEFINITIONS

Many basic terms have varying meanings within the computer industry, depending upon the role of the person speaking. In this report, such terms are used in the way most disk drive manufacturers use them.

Market classification

Market class is used here, arbitrarily, to differentiate Captive, Distributor and OEM/Integrator disk drive marketing activities.

Captive: Disk drives manufactured internally or by a subsidiary of a system manufacturer, and sold or leased primarily for use with the manufacturer's systems. Note that the term is used to describe the products, not the manufacturer; drives sold to Distributor or OEM/Integrator market classes are classified accordingly.

Examples:

- Optical disk drives manufactured and sold by Sony with a computer system to an end user are considered captive.

Noncaptive: Any public sale or lease by any disk drive manufacturer, except sales or leases of internally manufactured products by computer system manufacturers primarily for use with their own computer systems. Both OEM/Integrator and Distributor shipments are included in the noncaptive sales channel.

Examples:

- Disk drive shipments by Matsushita Electric are considered noncaptive, except for drives sold with systems made by the parent company or other subsidiaries.
- Shipments made by Calluna, Iomega, Maxoptix or Citizen are noncaptive.

Distributor: Disk drives sold in the "aftermarket" -- shipments by disk drive manufacturers to subsystem producers, value-added resellers, distributors, retail chains, mail-order firms and individual dealers. It includes drives to be connected to systems of all types, including personal computers, minicomputers and mainframes, or products sold as add-on devices by distributors and dealers.

Examples:

- Rigid disk cartridge drives from Iomega or Castlewood.
- Iomega Zip drives sold through industrial distributors.

OEM/Integrator: Drives sold by the original producer to system manufacturers which resell them as part of complete computer systems. Also includes sales to system integrators that combine finished system components and software to provide complete systems for specific applications. Sales by a disk drive manufacturer to a second drive manufacturer for resale are included only in shipment totals for the originating manufacturer, except when products are produced on a contract manufacturing basis with a design supplied by the disk drive manufacturer that finally sells the product to a third party.

Examples:

- Disk drives produced by Lite-On or Toshiba for sale to system manufacturers.
- Clik! drives sold by Iomega directly to digital camera manufacturers.

Geographic classification

Geographic analysis is based upon U.S. and non-U.S. regions. Together, these two regions comprise the worldwide market.

U.S. vs. Worldwide SHIPMENTS: Shipments are classified U.S. or worldwide depending on the country in which the headquarters of the purchasing company is located.

Examples:

- An OEM shipment by a U.S. drive manufacturer to a European system manufacturer is included in worldwide totals, even if the product is integrated into a system within the U.S.
- An OEM shipment by a Japanese drive manufacturer to a U.S. based system manufacturer is included in U.S. totals, even if the drive or card is integrated into a system in Taiwan, regardless of the final destination of systems in which the storage devices are used.

U.S. vs. Non-U.S. MANUFACTURERS: Manufacturers are classified U.S. or non-U.S., depending on the location of the firm's headquarters, regardless of the location of individual manufacturing plants. Subsidiary corporations are classified according to the geographical location of their parent organization's headquarters.

Example:

- Iomega and IBM are considered U.S. manufacturers, even though the companies manufacture many data storage devices in non-U.S locations.

Units of measurement

Drives: The basic unit in counting disk drives. One disk drive assembly consists of the disk drive mechanism required to utilize a single disk or disk stack.

Revenue: Based on sales of disk drives alone, as normally sold by individual manufacturers. Controllers sold as separate units are not included in disk drive revenue, nor are removable disk media, spare parts or service. When individual storage device models include integral control functions, such as may be required for the first drive on a string of drives, the actual value of the complete unit is used. Sale prices are estimated public sale transaction prices, whether at captive end user, Distributor or OEM/Integrator levels. All prices are in 1999 constant dollars.

Forecasts: Expected shipments and revenues for current or announced products in new production. Evolutionary improvements within existing disk drive formats are included, but completely new configurations or technologies are not included.

Examples:

- Enhancements such as future double density versions of existing single density product configurations and revised encoding schemes anticipated in DISK/TREND forecasts.
- Innovations such as nonstandard size disks or new physical configurations may require establishment of new DISK/TREND product groups or product subgroups.

Application classification

Shipments of removable storage drives are classified by the following computer applications:

Specialized high performance systems: Attached directly to the processor or to a terminal associated with a supercomputer, video server or editing system, or a high-end imaging system.

Mainframe systems: Attached directly to the processor or to a terminal associated with a general purpose mainframe computer system.

Networks/midrange systems: Used with network file servers, minicomputers and other midrange multiuser systems. Examples: IBM AS/400, Hewlett-Packard 3000, Compaq ProLiant, Data General CLARiiON series, workstations used for engineering, graphics, medical and other applications.

Desktop personal computers: Used with a personal computer intended primarily for nonconsumer applications. Examples: IBM PC series, Dell Dimension series, Apple Macintosh.

Consumer computers: Desktop personal computers sold to consumers primarily for nonbusiness purposes, and dedicated application systems for computer games and other applications.

Portable computers: Laptop, notebook, subnotebook and smaller general purpose and specialized computer systems.

Other applications: Any other application not included above, including uses such as video set top boxes, intelligent fax machines, copiers, scanners, intelligent personal communication devices, automotive navigation systems, digital cameras, factory data collection equipment, etc.

CD-ROM OPTICAL DISK DRIVES

CD FORMAT READ-ONLY OPTICAL DISK DRIVES

Coverage

Examples of disk drives in this group include:

12 centimeter (4.72") disk diameter

Acer Peripherals	CD-640P, CD-648A
Actima	A44T, A50T
Afreey	CD-184DE, CD-2255E
AOpen	CD-940E, CD-956E
Asustek Computer	CD-S400, CD-S500
Behavior Tech Computer	BCD-40SB, BCD40XH
Delta Electronics	OIP-CD4800A
EPO	CR-836S, CR-848S
Hitachi	CDR-8430
Kenwood Research	UCR-412
Leoptics	CDD-1400, CDD-1500
LG Electronics	CRD-8320B, CRD-8480B
Lite-On Technology	LTN-323, LTS-321
Matsushita Electric Industrial	CR-175-B, CR-593-B, UJDA150
Mitsumi Electric	FX320M, SR242S
Mountain Optech	CS-680, SI-680
Nakamichi	MJ-5.16S
NEC Home Electronics	CDR-2800B, CDR-3010, CDR-1810A
Pan-International (Cyberdrive)	CD400D, CS240D
Philips	PCA 20, PCA 32
Pioneer	DRM-6NX
Plextor (Shinano Kenshi)	PX-32CS, PX-50TSi
Samsung Electronics	SC-140, SCR-2437
Sanyo Electric	CRD-1332P
Sony	CDU-701, PRD-650MC
Tatung	CD-1640E, CD-1648E
TEAC	CD-224E, CD-524E
Toshiba	XM-6302B, XM-1902B, XM-6502B
Ultima Electronics (Artec)	Super-40X, Super-50X
Wearnes Peripherals	CDS-36x Max, CDS-32x Max

A standard CD-ROM optical drive is equipped only to read an appropriate optical disk. It does not have a laser capable of developing write power, a method to switch the laser into a writing mode, nor electronics required for writing data. The optical read-only drive is sometimes referred to as OROM (Optical

Read-Only Memory), but all drives in this product group are of the CD-ROM type and use 12 centimeter (4.72") or 8 centimeter (3.15") media. 12 centimeter drives usually also accept 8 centimeter media. DVD-ROM drives are covered in section REMOV2 of this report, and writable CD format drives (CD-R, CD-RW, DVD-R, DVD-RAM, DVD+RW) are covered in section REMOV3 of this report, which follow this product group. In this report, CD audio players equipped with electronics to read CD-ROM formatted disks are counted as CD-ROM drives. Drives of this type are most often used with electronic games or other consumer applications.

CD-ROM drives and media are a form of electronic publishing. A mass replication process analogous to the printing of a book or the stamping of a phonograph record is used to place data on disks, although CD-ROM drives can also read CD-R or CD-RW media. Demand for CD-ROM drives is driven by the quantity and types of information that publishers provide. In addition to the more than 20,000 titles now sold to the public by CD-ROM publishers, there are numerous "titles" published by companies for internal use. Typical internal titles include catalogs, parts lists, policy/procedure manuals, and equipment maintenance documentation. The desire to publish internally distributed data has spawned a do-it-yourself CD-ROM publishing industry that continues to grow as the price of authoring tools and equipment comes down and usage is simplified.

Market status

CD-ROM drive shipments rose again in 1998, although short product life cycles and intense price competition continued to reduce profitability for most industry participants. Competitors in Korea and Taiwan caused OEM prices to dip well below the 40 dollar range for desktop ATAPI drives. The speed race, once thought slowed, was rekindled by the explosive growth of the low-end PC market, with major sales of 40X to 48X drives into that segment. 50X and 56X drives have appeared in aftermarket channels and in the product lines of a few OEMs. Personal computer manufacturers remain the greatest demand source for CD-ROM drives as a result of the increasing number of multimedia software products being shipped. The industry is continuing its transition to DVD-ROM drives. DVD shipments, though hampered by lack of titles and higher prices, continued to ramp up in 1998, although 1998 CD-ROM shipments far outnumbered DVD-ROM drive shipments. CD-ROM drives capable of reading CD-RW media began production in late 1996 and this capability is now a standard feature.

1998 unit shipments rose 23.2% to nearly 91.9 million units, displaying unexpectedly strong growth as a result of the surge in low price personal computer sales. 1998 worldwide sales revenues declined (for the first time) 15.5% to nearly $4.3 billion. The drop in sales revenue was driven by declining prices resulting from competition, and particularly competition from Korean and Taiwanese producers. The rapidly shrinking profits and a shift to DVD production capacity caused many Japanese producers to reduce output, and some smaller manufacturers, unable to keep up with declining prices, have ceased assembling CD-ROM drives. With the exception of Philips, all of the currently active non-U.S. suppliers are Asian companies. A few ruggedized drives are produced in the United States by companies that use purchased mechanisms.

For the first time, a non Japanese company was the shipment leader. 1998 noncaptive CD-ROM drive shipments were led by LG Electronics, followed by TEAC, Lite-On (Taiwanese), and Toshiba. Toshiba is the leading captive producer on the strength of sales of notebook computer products.

Thin CD-ROM drives, now available from multiple manufacturers for use with notebook computers, accounted for almost 7.8 million units (8.5%) of the 1998 total shipments.

Marketing trends

CD-ROM drive shipment growth is expected to peak at 94.9 million drives in 1999, declining subsequently as DVD-ROM drive shipments displace CD-ROM drive shipments. 48X is expected to be the last major transition for CD-ROM, although 50X and 56X drives will have a place in aftermarket channels and a limited role in high end personal computer manufacturers' products. Refer to the following product section for a discussion of DVD-ROM trends. CD-ROM shipments will decline to 30.3 million units in 2002, surpassed by DVD-ROM shipments of over 92.8 million units. 1997 was actually the peak year for CD-ROM revenues at $5.08 billion. Rapidly declining prices in 1998 and declining volume in 2000 and after will lead to a decline in revenues to $803.4 million in 2002.

Average OEM prices are expected to drop well below thirty dollars due to increasing competition from companies producing in Korea, China, Taiwan and Southeast Asia.

Non-U.S. firms will continue to be the major producers, but Asian countries other than Japan are expected to continue to improve their share of the market as Japan shifts its attention to DVD-ROM drives. Some CD-ROM contract production has moved from Japan to other Asian locations, and this is stimulating local manufacturing of CD-ROM drives, particularly in China. Even some non-Japanese producers have shifted some or all of their production to China in order to reduce costs.

OEM shipments are expected to decrease as a percentage of total shipments as production shifts to DVD. Distributor shipments, 34% of 1998 shipments, are expected to increase as a percentage of total shipments to 40.1% in 2002. Captive shipments are expected to decline slightly from 7.3% in 1998 to 4.5% in 2000 as a result of a shift to DVD production by notebook computer manufacturers that also produce drives. Much of the remaining captive production is expected to be slim form factor drives for low-end notebook computers.

Applications

CD-ROM drives are used mostly with microcomputer based systems, including personal computers, multiple user microcomputers and network servers, computer games and consumer appliances based upon microcomputers. So far, the introduction of network computers has had only moderate impact on CD-ROM shipments. Portable applications and consumer applications, including home computing, have become fast growing areas of CD-ROM use.

CD-ROM has the inherent capability to store and recover digitized images and audio, a characteristic which promotes applications in technical training, language instruction, and other educational uses. The generic ability to handle text, audio and video data is often referred to as "multimedia". Multimedia is not restricted to any particular type of storage medium, but the large amounts of storage required by digitized audio and video make CD-ROM an appropriate vehicle for distribution of multimedia titles. Widespread acceptance of video on CD awaits the DVD drives that permit a single disk to contain two hours of video.

In 1998, 63.1% of the CD-ROM drives shipped were attached to desktop personal computers, while portable computers accounted for 12.2%. About two thirds of the portable systems used slim form factor drives. Consumer computer and other applications, notably games such as Sony's Playstation, captured 16.4% because of growth in lower cost PC shipments. CD-ROM drives used with network servers and workstations claimed 7.1% in 1998, about the same as in 1997. CD-ROM drives used in optical libraries and in CD-ROM towers attached to file servers or directly attached to the network are included in this segment. Many of these servers are used to supply business data across a corporate "Intranet", a local area network supporting Internet addressing conventions.

Desktop personal computers are expected to continue as the largest application for CD-ROM drives in 2002, capturing 36.8% of the drive shipments. Consumer applications, led by entertainment, home computing and education uses, are expected to be the second largest application area, with 31.1% of the units sold, followed closely by portable applications with 30.1%. Network servers and workstations will use only 1.1% of the drives shipped, as these platforms are expected to shift quickly to DVD-ROM use.

In the consumer applications area, games, education, music and arts, and numerous special interest subjects are significant applications of CD-ROM and related multimedia technology, but there is significant overlap of educational and reference titles between consumer, business and education markets. Because the sales of drives for consumer market PCs are very cost sensitive, the lower cost of CD-ROM compared to DVD-ROM (currently about $50) favors the use of CD over DVD in consumer applications at present.

The majority of major software producers preferentially distribute their software and documentation on CD-ROM because the cost of replication and packaging is substantially less than when multiple floppy disks are used. Installation is also (usually) easier and faster for the end user. CD-ROM disks have become one of the most widely used media for distribution of software from independent publishers. Other types of company data distributed on CD-ROM include product information and product demonstrations, with some disks containing software and on-line manuals that can be installed from the CD-ROM demo disk. The software author provides an unlock code after customer payment so that installation is enabled.

Business use of CD-ROM drives is oriented towards reference and training uses. Reference materials may include purchased data bases or may be internally generated documents such as parts lists or customer data. For instance, MCI distributes billing data on CD-R disks, permitting customers to analyze billings on systems equipped with CD-ROM drives. IBM was early to place its "universal sales manual" on CD-ROM and continues to update it monthly. And numerous firms provide databases of phone numbers, maps and other reference materials.

Education and industrial training are current areas of applications strength for CD-ROM, and these segments have become early and significant users of CD-ROM multimedia capabilities. A broad range of titles are being marketed to both consumer and education markets, and many companies have their service manuals on CD-ROM to take advantage of multimedia capabilities.

Government use of CD-ROM has expanded rapidly, because CD-ROM use permits major savings in printing, inventory, storage and distribution costs. In some cases, it has been possible to make government statistics and documentary information available to the general public that was not previously available due to the cost of distribution. SIGCAT, a special interest group promoting CD/DVD technology within the government, has helped expand usage. Where governments use CD-ROM to distribute libraries of forms, the process of updating the forms is simpler because only a new disk needs to be sent and the number of obsolete forms discarded can be reduced. A widely distributed government produced CD-ROM concerns the management of hazardous materials. The military services use CD-ROM storage in place of paper operations and maintenance materials, saving substantial weight and space and simplifying logistics.

CD-ROM and DVD-ROM titles that operate with software allowing access to the Internet (or Intranets) are increasingly common, with the disk containing Internet links to web sites that support or interact with the content of the disk.

Technical trends

The basic technology utilized in this product group was derived from the consumer CD player, with significant product differentiation based primarily on performance and embedded features. DVD-ROM drives have expanded upon CD-ROM technology as a result of pressures to increase the ability of the disk to contain increased video and audio content. Because of incompatibility issues concerning CD-R and CD-RW media, CD-ROM drives evolved rapidly in 1997, and now handle all types of CD-format media, but not DVD media because of the shorter wavelength laser required. Because CD-ROM drives are nearing the end of their product cycle, new development efforts have shifted to DVD-ROM, except for those concerned with size and cost reduction.

Caddy: CD-ROM drives used in critical applications may require a cartridge (caddy) to contain the disk. The cartridge holds the disk in place within the drive, preventing loss of focus due to vibration, shock, or mounting in other than a horizontal position. This permits the drive to be used in high shock/vibration environments such as motor vehicles and optical libraries, or mounted in a vertical position within a system enclosure.

Because of cost pressures, most CD-ROM designs have done away with the caddy and use top loading or powered tray loading designs. However, the reliability and avoidance of handling damage provided by caddies continues to make them desirable in high-end drives used with high performance CD-ROM libraries.

Jukebox designers may find caddies easier for high speed picker mechanisms to handle than unprotected disks and more reliable as well, although lower performance, lower cost libraries seem to handle unenclosed disks satisfactorily.

Standards: The early establishment of the Sony/Philips de facto standards for CD-ROM became the basis for CD-ROM physical disk interchangeability and provided a mechanism for identification of a disk and files upon the disk. The High Sierra group, an ad hoc task force consisting of a group of companies interested in CD-ROM, subsequently prepared a proposed recording standard and submitted it in 1986 to ANSI and ECMA. This became ISO standard 9660.

ISO 9660 required modification to fit the needs of the UNIX operating system, and an ad hoc task force called the Rock Ridge group prepared proposals to that end. A further extension to cover multisession recording became the ECMA 168 standard.

Standards for motion video compression worked out by MPEG (Motion Picture Experts Group) were first adopted for CD-I, with the first MPEG decoder chips available in 1992. However, full screen picture quality using MPEG-1 was considered by many to offer inferior image quality compared to conventional VHS videotape, so an improved version, MPEG-2 was developed to fully activate the CD-ROM/DVD-ROM based video market. A similar group, JPEG, is concentrating on compression standards for still video images. These standards, while important for multimedia software generally, will apply regardless of the storage device used.

Performance: Average access times have dipped to well under 100 milliseconds and seek times have dipped under 80 milliseconds. Users are getting faster data transfer rates by means of faster rotation rates. CD-ROM drive producers routinely manufacture drives with at least 32 times the original 150 KB/second data transfer rate, with the improvement in performance achieved by increasing the rotation rate and moving from constant linear velocity (variable spin rate) to constant angular velocity (fixed spin rate). As spin rates increased above 6,000 RPM, drive designers discovered that mechanical instabilities made further RPM increases difficult. Undesirable noise and vibration also result, frequently causing read errors. As a result, drives adopted constant angular velocity (CAV) design or hybrid CAV/CLV designs as they moved above 12X speeds in order to limit the spin rates required. The consequence is that instead of exhibiting a constant linear velocity and a nearly constant internal data transfer rate, drives now exhibit a range of rates, with the slowest on the inner tracks, increasing as the head approaches the outer tracks. Rotation rate has increased to 10,000 RPM for the fastest drives, but the drive frequently must drop back to lower speeds to read the disks reliably. Although the drive requires more sophisticated electronics to handle the high RPM situation, suitable chip sets are available. Oak Technology, Cirrus Logic and other controller makers are offering controllers or chip sets that can extend data transfer rates to the 40X-50X range.

The presence of a large buffer is important for adequate multimedia performance. 128 kilobyte buffers are a minimum requirement, but drives with 256 kilobyte or larger buffers are increasingly preferred for multimedia applications. The larger buffers are appropriate for application requiring smooth full motion video and/or higher data transfer rates. Higher performance drives also increase pressure for higher capacity, because the faster drives encourage increasing the video content of the application stored on the disk.. The desire for increased capacity further stimulates migration to DVD-ROM by system producers.

Software: Development of software for use with major operating systems and application programs, such as text search and the spectrum of multimedia applications, continues. Additional software is needed to support the new generation of high capacity DVD drives as they enter the marketplace. Newer operating systems, such as Windows 98, can support CD-ROM and DVD-ROM drives without the addition of third party software.

Interface: Initially, CD-ROM drives were typically designed with SCSI interfaces, with the SCSI-2 command set and small connector widely adopted in current CD-ROM drives. SCSI-2 is likely to remain the interface most used on servers because of its ability to use many devices. Cost pressures prompted the appearance of drives with interfaces specific to a sound card incorporated in a personal computer that also connects to the CD-ROM drive. Dedicated use systems, such as the CD-I players, use a proprietary interface, as do some multimedia add-on kits.

The IDE/ATAPI interface (originated by Western Digital) has been widely adopted by personal computer manufacturers because it is less expensive than SCSI, has SCSI-like performance, and permits adding CD-ROM drives to systems using the IDE interface for other storage devices. (IDE/ATAPI supports up to 4 devices, adequate for most small systems). Large shipments of drives with this interface began in the second half of 1994, and IDE/ATAPI became the most used interface in 1995, as a result of widespread adoption by personal computer manufacturers.

Future generations of desktop computers will employ serial bus structures such as USB and P1394 for the connection of peripheral devices. Drives with USB compliant interfaces appeared in 1998.

Cost reduction: Cost reduction programs are continuing and accelerating as a result of intense price competition. Plastic molded lenses, for instance, replaced polished glass lenses. In some low performance CD-ROM drives, stepping motors are used rather than more expensive positioning methods. Superfluous components, such as audio jacks and related circuitry, will be removed in some designs. Plastic has replaced sheet metal in some low end drive packaging. The costs of the electronic elements used are also declining with increasing CD-ROM drive shipment volume and use of more complex ASICs. Manufacturing in countries with low labor and overhead costs is increasingly common.

Packaging: The packaging of CD-ROM drives has changed rapidly. In 1986, most of the drives shipped were not compatible with the full height and half high form factors that have been adopted for 5.25" magnetic disk drive products. Today, CD-ROM drives are mostly half high models, though 12.7 millimeter high models are increasingly common, with the latter capable of fitting under the keyboard of a notebook computer. CD-ROM drives are frequently mounted externally to the thinnest or least expensive notebook computers, but internally in desktop, server or tower configurations. CD-ROM autochangers with up to 6 disk capacities have become available for installation, some in a single half high 5.25" drive bay.

Networks, libraries and CD-ROM towers: System integrators frequently add CD-ROM capabilities to file servers, but the slow access time of the CD-ROM led many server integrators to adopt multiple drive configurations, or CD-ROM towers. The CD-ROM tower typically holds from 4 to 28 drives, although 7 drives is the most common size.

Early towers typically had a SCSI interface to a server, but these have largely been displaced by towers or autochangers that attach directly to a local area network and can be configured to operate with one of several available network protocols. Tower and autochanger designs include hard disk drives to cache multiple CD-ROM disk images, providing faster performance, reduced size and lower cost, as fewer drives are required and rigid disk drives are very inexpensive. Buyers shifted rapidly towards network attached cached towers because of their cost, flexibility, Internet compatibility, and ease of installation.

Writable CD: Writable CD-format (CD-R and CD-RW) media and systems are expensive but are becoming more affordable. Philips, Sony, Yamaha, JVC and Ricoh are among the firms currently shipping drives. Many companies are exploring the internal uses of rewritable CD-ROM format recording because of the large numbers of CD-ROM drives already installed or anticipated within their organizations. The CD-RW (CD-rewritable) drives proposed by Philips were introduced in late 1996 and have largely displaced CD-R drives. See the product section on CD/DVD format writable drives for a full discussion.

Potential competition: At the present time, CD-ROM/DVD-ROM is relatively unchallenged as an inexpensive publishing and data distribution technology. While small applications may be distributed on floppy disks, CD-ROM has superior economics for most software producers and is approaching ubiquity at sites where personal computers are installed. As noted earlier, DVD-ROM has begun rapidly displacing CD-ROM.

3.5" magneto-optic drives also have read-only capability and could be used in many of the same applications as CD-ROM drives. However, their higher prices make strong competition with CD-ROM drives unlikely.

High capacity floppy drives, currently offering 100-250 megabytes, do not have the capacity required for many applications, and the media is also more expensive. They are not significant competition for CD-ROM.

The rapidly declining costs and improving performance of CD-ROM and DVD-ROM make it increasingly unlikely that any competing technology can offer an effective challenge in the period of the forecast. The most significant competition to CD-ROM is likely to be writable versions such as CD-RW drives, and their DVD equivalents, which are expected to capture about 20% of the available drive slots in 2002.

Forecasting assumptions

1. CD-ROM drive production capability will more than meet demand, although short-term component shortages may occur as the industry infrastructure retools to support DVD.
2. 48X will be the last major CD-ROM generation. 50X and 56X drives will capture only minor shares.
3. Non-U.S. suppliers will continue to dominate the CD-ROM hardware market, with most production in Asia.
4. There will be little impact on CD-ROM shipments from competing technologies throughout the forecast period, except for CD-RW and DVD-ROM.
5. Most consumers will prefer to use CD-ROM based games and educational materials with personal computers rather than with freestanding players.
6. Media mastering and replicating capacity will be adequate and will not restrict growth for CD-ROM optical memory markets. Replication quality will be available for 32X and higher operating rates, but not all publishers will take advantage of it.
7. Cost reduction and strong competitive pressure will continue and result in a continued decline in average drive prices.

TABLE 9

CD-ROM OPTICAL DISK DRIVES

REVENUE SUMMARY

	DISK DRIVE REVENUES, BY SHIPMENT DESTINATION ($M)									
	1998 Revenues		Forecast 1999		2000		2001		2002	
	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW
U.S. Manufacturers										
TOTAL U.S. REVENUES	--	--	--	--	--	--	--	--	--	--
Non-U.S. Manufacturers										
Captive	61.3	491.5	20.5	330.0	17.7	231.1	6.3	113.6	1.5	56.1
Distributor	437.4	1,353.6	315.9	984.4	289.3	869.1	208.0	625.3	105.1	296.0
OEM/Integrator	861.5	2,445.7	679.5	2,215.1	440.7	1,468.0	232.9	865.8	104.5	451.3
TOTAL NON-U.S. REVENUES	1,360.2	4,290.8	1,015.9	3,529.5	747.7	2,568.2	447.2	1,604.7	211.1	803.4
Worldwide Recap										
TOTAL WORLDWIDE REVENUES	1,360.2	4,290.8	1,015.9	3,529.5	747.7	2,568.2	447.2	1,604.7	211.1	803.4
OEM Average Price ($000)		.045		.036		.030		.028		.026

TABLE 10

CD-ROM OPTICAL DISK DRIVES

UNIT SHIPMENT SUMMARY

	DISK DRIVE UNIT SHIPMENTS, BY SHIPMENT DESTINATION (000)									
	1998 Shipments		Forecast							
			1999		2000		2001		2002	
	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW
U.S. Manufacturers										
TOTAL U.S. SHIPMENTS	--	--	--	--	--	--	--	--	--	--
Non-U.S. Manufacturers										
Captive	1,060.0	6,744.0	530.0	6,090.0	488.6	4,994.1	190.7	2,616.4	49.0	1,364.0
Distributor	10,041.0	31,252.5	9,149.0	28,329.0	9,866.8	29,650.8	7,974.5	23,949.7	4,329.8	12,142.2
OEM/Integrator	19,972.8	53,896.4	19,937.0	60,512.0	16,075.3	48,164.3	9,143.2	30,283.3	4,436.7	16,758.8
TOTAL NON-U.S. SHIPMENTS	31,073.8	91,892.9	29,616.0	94,931.0	26,430.7	82,809.2	17,308.4	56,849.4	8,815.5	30,265.0
Worldwide Recap										
TOTAL WORLDWIDE SHIPMENTS	31,073.8	91,892.9	29,616.0	94,931.0	26,430.7	82,809.2	17,308.4	56,849.4	8,815.5	30,265.0
Cumulative Shipments (Units in millions)										
WORLDWIDE TOTAL	127.9	305.1	157.6	400.0	184.0	482.8	201.3	539.7	210.1	569.9

TABLE 11

CD-ROM OPTICAL DISK DRIVES

WORLDWIDE REVENUES ($M)

BREAKDOWN BY DRIVE TYPE

	1998 Revenues		Forecast 1999			2000			2001			2002		
	<=32X	33X-48X	<=32X	33X-48X	>48X	<=32X	33X-48X	>48X	<=32X	33X-48X	>48X	<=32X	33X-48X	>48X
U.S. MANUFACTURERS														
TOTAL U.S. REVENUES	--	--	--	--	--	--	--	--	--	--	--	--	--	--
NON-U.S. MANUFACTURERS														
Captive	463.9	27.6	184.3	145.7	--	111.8	119.3	--	71.4	42.2	--	44.4	11.7	--
Distributor	1,054.9	298.7	248.6	719.3	16.5	130.5	695.9	42.7	46.5	515.0	63.8	4.1	249.7	42.2
OEM/Integrator	2,193.2	252.5	1,256.6	957.8	.7	568.9	893.6	5.5	395.5	457.7	12.6	229.4	204.6	17.3
TOTAL NON-U.S. REVENUES	3,712.0	578.8	1,689.5	1,822.8	17.2	811.2	1,708.8	48.2	513.4	1,014.9	76.4	277.9	466.0	59.5
WORLDWIDE RECAP														
Captive	463.9	27.6	184.3	145.7	--	111.8	119.3	--	71.4	42.2	--	44.4	11.7	--
	-12.5%	--	-60.3%	+427.9%	--	-39.3%	-18.1%	--	-36.1%	-64.6%	--	-37.8%	-72.3%	--
Distributor	1,054.9	298.7	248.6	719.3	16.5	130.5	695.9	42.7	46.5	515.0	63.8	4.1	249.7	42.2
	-38.4%	--	-76.4%	+140.8%	--	-47.5%	-3.3%	+158.8%	-64.4%	-26.0%	+49.4%	-91.2%	-51.5%	-33.9%
OEM/Integrator	2,193.2	252.5	1,256.6	957.8	.7	568.9	893.6	5.5	395.5	457.7	12.6	229.4	204.6	17.3
	-22.6%	--	-42.7%	+279.3%	--	-54.7%	-6.7%	+685.7%	-30.5%	-48.8%	+129.1%	-42.0%	-55.3%	+37.3%
Total Revenues	3,712.0	578.8	1,689.5	1,822.8	17.2	811.2	1,708.8	48.2	513.4	1,014.9	76.4	277.9	466.0	59.5
	-26.9%	--	-54.5%	+214.9%	--	-52.0%	-6.3%	+180.2%	-36.7%	-40.6%	+58.5%	-45.9%	-54.1%	-22.1%
ANNUAL SHARE, BY DIAMETER	86.6%	13.4%	48.0%	51.6%	.4%	31.6%	66.6%	1.8%	32.0%	63.3%	4.7%	34.7%	58.0%	7.3%

TABLE 12

CD-ROM OPTICAL DISK DRIVES

WORLDWIDE SHIPMENTS (000)

BREAKDOWN BY DRIVE TYPE

	1998 Shipments		Forecast 1999			2000			2001			2002		
	<=32X	33X-48X	<=32X	33X-48X	>48X	<=32X	33X-48X	>48X	<=32X	33X-48X	>48X	<=32X	33X-48X	>48X
U.S. MANUFACTURERS														
TOTAL U.S. SHIPMENTS	--	--	--	--	--	--	--	--	--	--	--	--	--	--
NON-U.S. MANUFACTURERS														
Captive	6,274.0	470.0	2,650.0	3,440.0	--	1,696.7	3,297.4	--	1,323.1	1,293.3	--	986.4	377.6	--
Distributor	24,290.5	6,962.0	6,982.0	20,967.0	380.0	4,433.6	23,996.0	1,221.2	1,833.8	20,057.8	2,058.1	173.3	10,406.8	1,562.1
OEM/Integrator	47,390.4	6,506.0	31,260.0	29,232.0	20.0	14,882.0	33,099.1	183.2	11,509.9	18,304.2	469.2	7,225.1	8,867.9	665.8
TOTAL NON-U.S. SHIPMENTS	77,954.9	13,938.0	40,892.0	53,639.0	400.0	21,012.3	60,392.5	1,404.4	14,666.8	39,655.3	2,527.3	8,384.8	19,652.3	2,227.9
WORLDWIDE RECAP														
Captive	6,274.0	470.0	2,650.0	3,440.0	--	1,696.7	3,297.4	--	1,323.1	1,293.3	--	986.4	377.6	--
	+11.8%	--	-57.8%	+631.9%	--	-36.0%	-4.1%	--	-22.0%	-60.8%	--	-25.4%	-70.8%	--
Distributor	24,290.5	6,962.0	6,982.0	20,967.0	380.0	4,433.6	23,996.0	1,221.2	1,833.8	20,057.8	2,058.1	173.3	10,406.8	1,562.1
	-8.1%	--	-71.3%	+201.2%	--	-36.5%	+14.4%	+221.4%	-58.6%	-16.4%	+68.5%	-90.5%	-48.1%	-24.1%
OEM/Integrator	47,390.4	6,506.0	31,260.0	29,232.0	20.0	14,882.0	33,099.1	183.2	11,509.9	18,304.2	469.2	7,225.1	8,867.9	665.8
	+11.4%	--	-34.0%	+349.3%	--	-52.4%	+13.2%	+816.0%	-22.7%	-44.7%	+156.1%	-37.2%	-51.6%	+41.9%
Total Shipments	77,954.9	13,938.0	40,892.0	53,639.0	400.0	21,012.3	60,392.5	1,404.4	14,666.8	39,655.3	2,527.3	8,384.8	19,652.3	2,227.9
	+4.5%	--	-47.5%	+284.8%	--	-48.6%	+12.6%	+251.1%	-30.2%	-34.3%	+80.0%	-42.8%	-50.4%	-11.8%
ANNUAL SHARE, BY DIAMETER	84.9%	15.1%	43.2%	56.5%	.3%	25.4%	73.0%	1.6%	25.8%	69.9%	4.3%	27.7%	65.0%	7.3%

TABLE 13

CD-ROM OPTICAL DISK DRIVES

WORLDWIDE SHIPMENTS (000)

DRIVE HEIGHT ANALYSIS

	1998 Shipments		Forecast 1999		Forecast 2000		Forecast 2001		Forecast 2002	
	Units	%	Units	%	Units	%	Units	%	Units	%
U.S. MANUFACTURERS										
Total U.S.	--		--		--		--		--	
NON-U.S. MANUFACTURERS										
Captive Total	6,744.0		6,090.0		4,994.1		2,616.4		1,364.0	
Half High	5,144.0	76.3%	4,490.0	73.7%	3,406.5	68.2%	1,293.3	49.4%	377.6	27.7%
Slim	1,600.0	23.7%	1,600.0	26.3%	1,587.6	31.8%	1,323.1	50.6%	986.4	72.3%
Noncaptive Total	85,148.9		88,841.0		77,815.1		54,233.0		28,901.0	
Half High	78,949.9	92.7%	79,333.0	89.3%	65,629.7	84.3%	43,025.1	79.3%	21,675.9	75.0%
Slim	6,199.0	7.3%	9,508.0	10.7%	12,185.4	15.7%	11,207.9	20.7%	7,225.1	25.0%
Total Non-U.S.	91,892.9		94,931.0		82,809.2		56,849.4		30,265.0	
Half High	84,093.9	91.5%	83,823.0	88.3%	69,036.2	83.4%	44,318.4	78.0%	22,053.5	72.9%
Slim	7,799.0	8.5%	11,108.0	11.7%	13,773.0	16.6%	12,531.0	22.0%	8,211.5	27.1%
WORLDWIDE SHIPMENTS										
Total Shipments	91,892.9		94,931.0		82,809.2		56,849.4		30,265.0	
	+23.2%		+3.3%		-12.7%		-31.2%		-46.7%	
Half High	84,093.9	91.5%	83,823.0	88.3%	69,036.2	83.4%	44,318.4	78.0%	22,053.5	72.9%
	+12.8%		-.2%		-17.5%		-35.7%		-50.1%	
Slim	7,799.0	8.5%	11,108.0	11.7%	13,773.0	16.6%	12,531.0	22.0%	8,211.5	27.1%
	--		+42.4%		+24.0%		-8.9%		-34.4%	

Notes: Percentage figures with plus/minus signs refer to year-to-year growth rates.

TABLE 14

CD-ROM OPTICAL DISK DRIVES

APPLICATIONS SUMMARY
Percentage of Worldwide Shipments

APPLICATION	1998 Estimate Units (000)	1998 Estimate %	2002 Projection Units (000)	2002 Projection %
SPECIALIZED HIGH PERFORMANCE Supercomputers, video and high end imaging	--	--	--	--
MAINFRAME SYSTEMS General purpose	--	--	--	--
NETWORK/MIDRANGE SYSTEMS Midrange systems, network servers and workstations	6,524.4	7.1	332.9	1.1
DESKTOP PERSONAL COMPUTERS Business and professional, single user	57,984.4	63.1	11,137.5	36.8
CONSUMER COMPUTERS Desktop PCs, game, and hobby computers	15,070.4	16.4	9,412.4	31.1
PORTABLE COMPUTERS Notebook and smaller mobile computers	11,210.9	12.2	9,109.8	30.1
OTHER APPLICATIONS	1,102.8	1.2	272.4	.9
Total	91,892.9	100.0	30,265.0	100.0

TABLE 15

CD-ROM OPTICAL DISK DRIVES

MARKET SHARE SUMMARY
Worldwide Shipments of Noncaptive Disk Drives

	1998 Net Shipments									
	To United States Destinations					Worldwide				
	Units (000)				%	Units (000)				%
Drive Manufacturers	<=32X	33X-48X	>48X	Total		<=32X	33X-48X	>48X	Total	
LG Electronics	4939.0	5.0	--	4944.0	16.5	11368.0	15.0	--	11383.0	13.4
TEAC	1158.0	--	--	1158.0	3.9	7236.0	--	--	7236.0	8.5
Lite-On Technology	1008.0	1845.0	--	2853.0	9.5	2240.0	4303.0	--	6543.0	7.7
Matsushita El. Ind.	1275.0	10.0	--	1285.0	4.3	6450.0	60.0	--	6510.0	7.6
Toshiba	3483.0	--	--	3483.0	11.6	6125.0	--	--	6125.0	7.2
Sony	2465.0	--	--	2465.0	8.2	5375.0	--	--	5375.0	6.3
Mitsumi Electric	2230.0	--	--	2230.0	7.4	4990.0	--	--	4990.0	5.9
Samsung Electronics	540.0	400.0	--	940.0	3.1	4000.0	900.0	--	4900.0	5.8
Acer Peripherals	940.0	570.0	--	1510.0	5.0	3460.0	940.0	--	4400.0	5.2
NEC	1540.0	340.0	--	1880.0	6.3	3050.0	600.0	--	3650.0	4.3
Other U.S.	--	--	--	--	--	--	--	--	--	--
Other Non-U.S.	5388.8	1877.0	--	7265.8	24.2	17386.9	6650.0	--	24036.9	28.1
TOTAL	24966.8	5047.0	--	30013.8	100.0	71680.9	13468.0	--	85148.9	100.0

DVD-ROM OPTICAL DISK DRIVES

1999 DISK/TREND REPORT

DVD FORMAT READ-ONLY OPTICAL DISK DRIVES

Coverage

Examples of disk drives in this group include:

12 centimeter (4.72") disk diameter

Acer Peripherals	DV-605A, DVD-606A
Actima	AD05P
Afreey	DD-3206
AOpen	DVD-9632, DVD-9836
Behavior Technology Computer	BDV 840HS
Digital Video Systems	DSR-600H
Hitachi	GD-2500
Leoptics	CDD-6060
LG Electronics	DRD-8060B, DRD-8080B
Lite-On Technology	LTD-051, LTD-081
Matsushita Electric Industrial	SR-8173B, SR-8584B
Pan-International(Cyberdrive)	DM832D
Philips	DRD-5200, PCA 532DK
Pioneer	DVD-A03, DVD-303
Raite Optoelectronics	RDR-106H
Samsung Electronics	SD-608, SD-606
Sony	DDU220E-06
Tatung	DVD-6232
TEAC	DV-22E, DV-25E
Toshiba	SD-C2102, SD-M1212

A DVD-ROM optical drive is equipped only to read an appropriate optical disk. It does not have a laser capable of developing write power, a method to switch the laser into a writing mode, nor electronics required for writing data. Drives in this product group are of the DVD-ROM type and accept 12 centimeter (4.72") or 8 centimeter (3.15") media. DVD-ROM drives currently read DVD-ROM, CD-ROM, CD-R and CD-RW media, and are expected to be able to read at least some DVD-writable media in 1999. CD-ROM drives are covered in section DT-20 of this report, and writable CD/DVD format drives (CD-R, CD-RW, DVD-R, DVD-RAM, DVD+RW) are covered in section DT-22 of this report. DVD consumer video players are not covered in this report, except for applications in video set-top boxes.

Like CD-ROM, DVD-ROM drives and media create a form of electronic publishing. A mass replication process analogous to the printing of a book or the stamping of a phonograph record is widely used to place data on disks. Demand for DVD-ROM drives is dependent upon the quantity and type of information provided by publishers, but demand is not entirely conditional on data in DVD format, as the drives can read CD-ROM media. Relatively few "titles" are currently available for the public from DVD-ROM publishers, but companies are expected to publish numerous titles for internal use, as drives using writable DVD formats become more available. More DVD-ROM titles are expected to become available in late 1999. Typical internal titles may include catalogs, parts lists, policy/procedure manuals, training manuals, and equipment maintenance documentation that require more capacity than available on CD-ROM or CD-RW drive. The desire to publish internally distributed data has spawned a do-it-yourself CD-ROM publishing industry that is expected to replicate itself in a DVD oriented world.

Market status

1998 was a good growth year for DVD-ROM drives, but acceptance continues to be limited by lack of titles, relatively high drive prices, and confusion caused by the writable DVD format war. Another major factor was the sudden expansion of the low price PC market, which requires the less expensive CD-ROM drives in order to meet cost targets. Computer manufacturers have been reluctant to commit to very large orders of DVD-ROM drives that are unable to read DVD-RAM or other writable DVD formats. Furthermore, many system purchasers have found more value in CD-RW drives than DVD-ROM. As a result, most DVD-ROM manufacturers fell far short of their shipment targets. These difficulties are expected to be partially resolved within the next 12 months. OEM prices have already dipped below the eighty dollar range and are expected to decline further by year end. DVD-ROM drives are expected to acquire the ability to read 4.7 gigabyte DVD-RAM media in late 1999, and a new generation of CD-RW drives shipping in 1999 will also be able to read DVD-ROM media.

It appears that the industry is repeating the same destructive "X" race that reduced CD-ROM profitability, producing short product life cycles and inventory problems for industry participants. The rapid evolution from 1X drives, through 2X drives, to 8X drives in 1999 threatens to cause inventory and component procurement problems for manufacturers that can adversely affect profitability. Producers located outside of Japan are particularly likely to experience procurement problems. Personal computer manufacturers are expected to be the greatest source of demand for DVD-ROM drives, as they are for CD-ROM drives.

1998 unit shipments leaped almost 376% to over 5.7 million units, while worldwide sales revenues exceeded $650 million. 1999 unit shipments and revenues are continuing this fast pace, with 1999 sales revenue expected to grow another 84%, while unit shipments more than double. This rapid transition is attracting new competitors, but newcomers (mostly firms in Korea and Taiwan) often find it difficult to obtain adequate supplies of components and mechanisms. Most newcomers purchase optical and mechanical mechanisms, completing the drive by adding their own electronics and packaging.

As with CD-ROM drives, with the exception of Philips, all of the currently active suppliers are Asian companies. Hitachi, Toshiba and Matsushita Electric were the leading 1998 noncaptive DVD-ROM drive producers.

Slim DVD-ROM drives have begun a volume ramp and are beginning to displace thin CD-ROM drives. About 10% of 1998 production consisted of slim form factor drives.

Marketing trends

The shipment growth of DVD-ROM drives is expected to be rapid for the next few years, with total shipments of DVD-ROM drives expanding to 92.8 million units in 2002 and exceeding CD-ROM drive shipments in 2001. Revenues for 2002 are expected to grow to over $4.2 billion. The average OEM price is expected to decline to $41 in 2002 as competition increases and cost reductions are achieved. As DVD-ROM prices approach the $50 range, they will become more attractive to low-end PC system makers, and the displacement of CD-ROM by DVD-ROM will accelerate. Combination CD-RW drives capable of reading DVD-ROM media are expected to appear in 1999. While desirable for their "all-in-one" feature set, their higher prices will tend to confine their appeal to the high end of the PC market. Slim DVD-ROM drive shipments are expected to grow at a faster than average rate, reaching nearly 18% of total shipments in 2002 due to expanding sales of portable systems and small footprint desktop systems.

As in previous years, non-U.S. firms will be the major DVD-ROM drive producers, with Asian countries other than Japan expected to become significant sources as components become more available. Production by Japanese manufacturers will move from Japan to other Asian locations as cost pressures build and the technology matures.

OEM shipments in 2002 are projected at 53% of the total, while distributor shipments will account for an anticipated 31% share. Captive shipments are expected to capture 16% share in 2002 as a result of the broadening of the base of suppliers and strong anticipated shipment growth for slim DVD-ROM drives in notebook computers made by the same companies that produce drives.

Applications

DVD-ROM drives are used with high end microcomputer based systems, including personal computers (both desktop and notebook), multiple user systems and network servers, and consumer systems based upon microcomputers. Consumer applications, including games and home computing, are expected to be among the fastest growing areas of DVD-ROM use as prices fall. Workstations, especially those used for content preparation, are also anticipated to be a rapidly growing, if niche, demand category.

In 1997, 74.4% of the DVD-ROM drives shipped were attached to business personal computers in 1998, but this is expected to decline to 46.9% in 2002. Portable computers, which accounted for only .8% in 1997, are forecast to capture a 16.8% share in 2002. Consumer computer applications, with 5.8% in 1998, are expected to expand their share to 16.8%. DVD-ROM drive use with network servers and workstations, an 8.4% share in 1998, is expected to increase to 11.6%, helped by DVD-ROM autochangers, DVD-ROM towers and libraries attached to file servers or directly attached to the network, and nearly universal use on servers.

Many software producers preferentially distribute their software and documentation on CD-ROM because the cost of replication and packaging is substantially less than replication using floppy disks. Installation is also (usually) easier and faster for the end user. Because DVD-ROM drives can also read CD-ROM media, software publishers will continue to use less expensive CD-ROM media for distribution until an increasing installed base or a need for increased content size makes software distribution on DVD-ROM economically attractive.

Business use of DVD-ROM, like CD-ROM, is expected to be oriented towards reference and training uses, but with a higher multimedia content. Reference materials may include purchased databases or internally generated documents such as parts lists or customer data. Education and industrial training, current areas of applications strength for CD-ROM, are expected to be significant users of DVD-ROM multimedia capabilities, but many corporate users have difficulty in envisioning a need for DVD-ROM capacity for other applications.

Government use of DVD-ROM is expected to lag other applications, partially because of inertia and partially because of the lead time to prepare suitable content. However, government agencies will probably purchase DVD-ROM drives in 1999 and later procurements in order to prepare for anticipated future needs.

DVD-ROM titles that operate with software allowing access to the Internet (or Intranets) are expected to be increasingly common, with the disk containing Internet links to websites that support or interact with the content of the disk.

Technical trends

DVD-ROM drives have expanded upon CD-ROM technology as a result of pressures to increase the ability of the disk to contain increased video and audio content. Because of incompatibility issues concerning CD-R and DVD-writable media, DVD-ROM drives evolved rapidly in 1997 and 1998 to resolve the issues. Manufacturers are expected to be in position to ship DVD-ROM drives that can read CD-ROM, CD-R, CD-RW, DVD-ROM and DVD-writable media by late 1999.

Compatibility: Early users of DVD-ROM drives discovered that their drives were incapable of reading CD-R media because CD-R media has low reflectivity at the shorter laser wavelengths used in DVD drives. Later DVD drives employ dual lasers in the pickup to provide compatibility. While a more elegant and less costly approach is to modify the media to broaden the high reflectance portion of the reflectivity spectrum, this has proven to be more difficult than originally anticipated. While second generation DVD-ROM drives resolved the CD-R/RW problems, they could not read DVD-RAM media, which has a different format. The problem isn't going away: The introduction of DVD+RW writable drives in late 1999 will put even more stress on the DVD-ROM drive designer to achieve universal compatibility. And the issue of how to handle the cartridge used to contain DVD-RAM media is still unresolved, as removing the media to insert it in a tray loaded drive may void the warranty on the media.

Multimedia support: DVD-ROM drives routinely incorporate the necessary support for audio and video content, but the full video capabilities require MPEG-2 compatibility. Currently, this requires an additional (and expensive) module or a very fast processor to do the MPEG-2 decoding via software. The new 450 megahertz or faster processors can handle the processing load without completely saturating the system, but users of older, slower systems or more modern low end PCs may have to pay for the additional MPEG electronics if they want good full screen, high resolution video performance.

Capacity: Data bases, games, system software and documentation may span several CD-ROM disks, and content providers are expected to use the capacity of DVD-ROM to move multiple disk content to a single disk. Game publishers have been the most active in making this move.

IBM developed the stacked disk approach in which several recording layers are bonded together, with the desired surface addressed by varying the focal point of the pickup lens. This approach is used in the DVD drive specification, which defines disks having 1 or 2 recorded surfaces on each side of the disks. The DVD drives employ shorter wavelength red lasers (635-650 nanometers), higher track densities (over 30,000 TPI) and higher bit densities. However, the multisurface disks have been harder for replicators to produce and have been used mostly for movies (where small signal dropouts are non-critical), and it is expected that 4.7 gigabyte disks will be the mainstream DVD-ROM standard for years to come.

Caddy: DVD-ROM drives used in critical applications may require a cartridge (caddy) to contain the disk. The cartridge holds the disk in place within the drive, preventing loss of focus due to vibration, shock, or mounting in other than a horizontal position, and permits the drive to be used in motor vehicles or to be mounted in a vertical position within a system enclosure. It also provides reliability in an optical library, protecting media against debris and damage while being moved. Jukebox designers may find caddies easier for high speed picker mechanisms to handle than unprotected disks, although lower performance, lower cost libraries seem to handle unenclosed disks satisfactorily.

Standards: DVD-ROM working standards generated by the potential producers of the drives are basically complete, although issues relating to copy protection were not completely resolved to everyone's satisfaction. The ISO 13346 compliant UDF (Universal Disk Format) standard developed by OSTA for 3.5" and 5.25" drives has been adopted for DVD drives, a major step towards insuring compatibility among future drives. As the standards for DVD writable drives, especially DVD-RAM, are finalized, manufacturers will be able to manufacture DVD-ROM drives capable of reading DVD-writable media.

Performance: Average access times for DVD-ROM drives are in the 100-150 millisecond range, and access times in CD-ROM reading mode have dipped under 100 milliseconds. Data transfer rates, now in the 4-5X range for desktop drives (1X is the original DVD-ROM rate of 1.37 megabytes per second), are expected to move to the 16X range by 2001. Data transfer rates for drives used in portable equipment will be lower. Because of the need to conserve power, spin rates are typically less.

When operating in CD-ROM mode, most DVD-ROM drives will provide at least 24X performance. The tendency will be to operate at 24X for notebook drives and 32X for desktop drives.

Interface: SCSI-2 is likely to remain the interface most needed for use with servers because of its ability to handle many devices. IDE/ATAPI interfaces will be used on most drives installed in a PC, while USB and P1394 are expected to be important in the aftermarket.

Packaging: DVD-ROM drive packaging follows that of CD-ROM drives. DVD-ROM drives are mostly half high models, but 17, and 12.7 millimeter high designs are being designed into notebook computers. 12.7 millimeter designs will become prevalent for thin models in 1999 and thereafter.

Networks, libraries and DVD-ROM towers: Manufacturers and integrators of optical storage subsystems plan to incorporate DVD-ROM drives into libraries and towers as soon as their customers indicate a demand for such products, and many were announced in early 1999. Most of the issues involved relate to appropriate software support, with OS qualified drivers and media management tools needed.

Reliability: While there appear to be no blatant reliability issues with DVD-ROM drives, the higher areal density compared to CD-ROM causes the drive to be more vulnerable to dust and other contaminants.

There remains some concern about disk reliability. Accelerated environmental testing shows a wide variety of resistance to temperature and humidity variations, with the major problems the result of imperfect sealing of the protective layer of the disk, especially at the edges. There have been problems with both CD-ROM and CD-R/RW media that operate correctly on CD-ROM drives but develop unacceptable error rates on DVD-ROM drives. Media replicators and drive producers seem to be overcoming these problems, but the use of multilayer DVD disks and higher spin rates exacerbate the situation.

Writable DVD: Writable DVD-format (DVD-RAM, DVD+RW, DVD-R, DVD-RW) media and systems are expensive, but becoming more affordable. Hitachi and Pioneer were among the first firms shipping, sometimes as part of a complete recording system. Companies exploring the uses of rewritable DVD format recording are hampered by the lack of authoring tools for DVD and the expense of available hardware and software.

Potential competition: At the present time, CD-ROM/DVD-ROM is relatively unchallenged as an inexpensive publishing and data distribution technology. CD-ROM currently has superior economics for most software producers, but this should not affect DVD-ROM sales unduly, since DVD-ROM drives now read all CD format media.

5.25" magneto-optic drives also have read-only capability and could be used in many of the same server and workstation applications as DVD-ROM drives. However, their much higher prices make strong competition with DVD-ROM drives unlikely except in workstation applications.

Rapidly declining costs and improving performance of DVD-ROM make it increasingly unlikely that any competing technology can offer an effective challenge in the period of the forecast. The most significant competition to DVD-ROM is likely to be writable versions such as DVD-RAM drives.

Forecasting assumptions

1. DVD-ROM drive production capability will substantially meet demand, although short-term component shortages may recur in 1999 and 2000 as rapid demand increases outstrip industry infrastructure capability.
2. DVD-ROM drive producers will undertake the same speed race that occurred in CD-ROM drives, but the number of competitors will be less.
3. Non-U.S. suppliers will continue to dominate the DVD-ROM hardware market, with most production outside the U.S.
4. There will be little impact on DVD-ROM shipments from competing technologies throughout the forecast period, except at the low price end of the PC market, where CD-ROM will compete for several years.
5. Most consumers will prefer to use DVD-ROM based games and educational materials with personal computers rather than with freestanding players.
6. Media mastering and replicating capacity will be adequate and will not restrict growth for DVD-ROM optical memory markets.
7. Cost reduction will continue and result in a long-term decline in average drive prices.

TABLE 16

DVD-ROM OPTICAL DISK DRIVES

REVENUE SUMMARY

	DISK DRIVE REVENUES, BY SHIPMENT DESTINATION ($M)									
	1998 Revenues		Forecast 1999		2000		2001		2002	
	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW
U.S. Manufacturers										
TOTAL U.S. REVENUES	--	--	--	--	--	--	--	--	--	--
Non-U.S. Manufacturers										
Captive	--	189.5	17.4	220.1	27.0	344.2	69.6	679.7	107.2	870.9
Distributor	81.0	158.4	154.3	424.2	221.8	623.3	366.3	1,009.5	493.6	1,333.5
OEM/Integrator	198.3	302.6	266.7	554.6	462.9	909.5	753.4	1,500.2	1,007.0	2,037.4
TOTAL NON-U.S. REVENUES	279.3	650.5	438.4	1,198.9	711.7	1,877.0	1,189.3	3,189.4	1,607.8	4,241.8
Worldwide Recap										
TOTAL WORLDWIDE REVENUES	279.3	650.5	438.4	1,198.9	711.7	1,877.0	1,189.3	3,189.4	1,607.8	4,241.8
OEM Average Price ($000)		.104		.084		.058		.048		.041

TABLE 17

DVD-ROM OPTICAL DISK DRIVES

UNIT SHIPMENT SUMMARY

	DISK DRIVE UNIT SHIPMENTS, BY SHIPMENT DESTINATION (000)									
	1998		Forecast							
	Shipments		1999		2000		2001		2002	
	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW
U.S. Manufacturers										
TOTAL U.S. SHIPMENTS	--	--	--	--	--	--	--	--	--	--
Non-U.S. Manufacturers										
Captive	--	1,246.0	174.0	1,848.8	345.0	4,440.0	993.3	9,939.3	1,805.5	14,826.6
Distributor	787.3	1,562.3	1,787.8	4,911.1	3,574.0	10,025.0	7,027.7	19,303.3	10,702.7	28,810.9
OEM/Integrator	1,916.8	2,898.1	3,212.8	6,591.9	7,998.0	15,624.0	15,765.8	31,080.1	24,706.1	49,194.9
TOTAL NON-U.S. SHIPMENTS	2,704.1	5,706.4	5,174.6	13,351.8	11,917.0	30,089.0	23,786.8	60,322.7	37,214.3	92,832.4
Worldwide Recap										
TOTAL WORLDWIDE SHIPMENTS	2,704.1	5,706.4	5,174.6	13,351.8	11,917.0	30,089.0	23,786.8	60,322.7	37,214.3	92,832.4
Cumulative Shipments (Units in millions)										
WORLDWIDE TOTAL	3.2	6.9	8.4	20.2	20.3	50.3	44.1	110.6	81.3	203.5

TABLE 18

DVD-ROM OPTICAL DISK DRIVES

WORLDWIDE REVENUES ($M)

BREAKDOWN BY DRIVE TYPE

	1998 Revenues			Forecast 1999				Forecast 2000			Forecast 2001			Forecast 2002		
	<=2X	3X-4X	5X-6X	<=2X	3X-4X	5X-6X	>=8X	3X-4X	5X-6X	>=8X	3X-4X	5X-6X	>=8X	3X-4X	5X-6X	>=8X
U.S. MANUFACTURERS																
NON-U.S. MANUFACTURERS																
Captive	82.3	42.4	64.8	--	120.4	73.6	26.1	150.6	26.0	167.6	98.8	212.1	368.8	9.9	297.3	563.7
Distributor	72.7	65.2	20.5	8.7	153.9	152.4	109.2	25.7	20.9	576.7	--	6.7	1,002.8	--	4.2	1,329.3
OEM/Integrator	171.4	84.5	46.7	1.6	107.5	281.7	163.8	42.1	63.6	803.8	48.4	68.9	1,382.9	71.5	82.3	1,883.6
TOTAL NON-U.S. REVENUES	326.4	192.1	132.0	10.3	381.8	507.7	299.1	218.4	110.5	1,548.1	147.2	287.7	2,754.5	81.4	383.8	3,776.6
WORLDWIDE RECAP																
Captive	82.3	42.4	64.8	--	120.4	73.6	26.1	150.6	26.0	167.6	98.8	212.1	368.8	9.9	297.3	563.7
	+404.9%	--	--	--	+184.0%	+13.6%	--	+25.1%	-64.7%	+542.1%	-34.4%	+715.8%	+120.0%	-90.0%	+40.2%	+52.8%
Distributor	72.7	65.2	20.5	8.7	153.9	152.4	109.2	25.7	20.9	576.7	--	6.7	1,002.8	--	4.2	1,329.3
	+30.8%	--	--	-88.0%	+136.0%	+643.4%	--	-83.3%	-86.3%	+428.1%	--	-67.9%	+73.9%	--	-37.3%	+32.6%
OEM/Integrator	171.4	84.5	46.7	1.6	107.5	281.7	163.8	42.1	63.6	803.8	48.4	68.9	1,382.9	71.5	82.3	1,883.6
	+61.4%	--	--	-99.1%	+27.2%	+503.2%	--	-60.8%	-77.4%	+390.7%	+15.0%	+8.3%	+72.0%	+47.7%	+19.4%	+36.2%
Total Revenues	326.4	192.1	132.0	10.3	381.8	507.7	299.1	218.4	110.5	1,548.1	147.2	287.7	2,754.5	81.4	383.8	3,776.6
	+83.3%	--	--	-96.8%	+98.8%	+284.6%	--	-42.8%	-78.2%	+417.6%	-32.6%	+160.4%	+77.9%	-44.7%	+33.4%	+37.1%
ANNUAL SHARE, BY DIAMETER	50.3%	29.5%	20.2%	.9%	31.9%	42.3%	24.9%	11.6%	5.9%	82.5%	4.6%	9.0%	86.4%	1.9%	9.0%	89.1%

Note: "<=" means "less than or equal to".
">=" means "greater than or equal to".

TABLE 19

DVD-ROM OPTICAL DISK DRIVES

WORLDWIDE SHIPMENTS (000)

BREAKDOWN BY DRIVE TYPE

	1998 Shipments			Forecast 1999				2000			2001			2002		
	<=2X	3X-4X	5X-6X	<=2X	3X-4X	5X-6X	>=8X	3X-4X	5X-6X	>=8X	3X-4X	5X-6X	>=8X	3X-4X	5X-6X	>=8X
U.S. MANUFACTURERS																
NON-U.S. MANUFACTURERS																
Captive	575.0	311.0	360.0	--	1,052.7	535.1	261.0	1,845.0	330.0	2,265.0	1,392.3	2,866.5	5,680.5	150.1	4,719.7	9,956.8
Distributor	657.3	727.2	177.8	95.7	1,818.3	1,785.2	1,211.9	405.0	343.0	9,277.0	--	100.8	19,202.5	--	71.7	28,739.2
OEM/Integrator	1,516.6	954.3	427.2	17.4	1,278.9	3,273.7	2,021.9	594.0	930.0	14,100.0	757.1	1,043.7	29,279.3	1,300.3	1,420.2	46,474.4
TOTAL NON-U.S. SHIPMENTS	2,748.9	1,992.5	965.0	113.1	4,149.9	5,594.0	3,494.8	2,844.0	1,603.0	25,642.0	2,149.4	4,011.0	54,162.3	1,450.4	6,211.6	85,170.4
WORLDWIDE RECAP																
Captive	575.0	311.0	360.0	--	1,052.7	535.1	261.0	1,845.0	330.0	2,265.0	1,392.3	2,866.5	5,680.5	150.1	4,719.7	9,956.8
	+458.3%	--	--	--	+238.5%	+48.6%	--	+75.3%	-38.3%	+767.8%	-24.5%	+768.6%	+150.8%	-89.2%	+64.7%	+75.3%
Distributor	657.3	727.2	177.8	95.7	1,818.3	1,785.2	1,211.9	405.0	343.0	9,277.0	--	100.8	19,202.5	--	71.7	28,739.2
	+85.2%	--	--	-85.4%	+150.0%	+904.0%	--	-77.7%	-80.8%	+665.5%	--	-70.6%	+107.0%	--	-28.9%	+49.7%
OEM/Integrator	1,516.6	954.3	427.2	17.4	1,278.9	3,273.7	2,021.9	594.0	930.0	14,100.0	757.1	1,043.7	29,279.3	1,300.3	1,420.2	46,474.4
	+104.7%	--	--	-98.9%	+34.0%	+666.3%	--	-53.6%	-71.6%	+597.4%	+27.5%	+12.2%	+107.7%	+71.7%	+36.1%	+58.7%
Total Shipments	2,748.9	1,992.5	965.0	113.1	4,149.9	5,594.0	3,494.8	2,844.0	1,603.0	25,642.0	2,149.4	4,011.0	54,162.3	1,450.4	6,211.6	85,170.4
	+129.3%	--	--	-95.9%	+108.3%	+479.7%	--	-31.5%	-71.3%	+633.7%	-24.4%	+150.2%	+111.2%	-32.5%	+54.9%	+57.3%
ANNUAL SHARE, BY DIAMETER	48.3%	34.9%	16.8%	.8%	31.2%	41.9%	26.1%	9.5%	5.3%	85.2%	3.6%	6.6%	89.8%	1.6%	6.7%	91.7%

Note: "<=" means "less than or equal to".
">=" means "greater than or equal to".

TABLE 20

DVD-ROM OPTICAL DISK DRIVES

WORLDWIDE SHIPMENTS (000)

DRIVE HEIGHT ANALYSIS

	1998 Shipments Units	1998 %	1999 Units	1999 %	2000 Units	2000 %	2001 Units	2001 %	2002 Units	2002 %
			Forecast							
U.S. MANUFACTURERS										
Total U.S.	--		--		--		--		--	
NON-U.S. MANUFACTURERS										
Captive Total	1,246.0		1,848.8		4,440.0		9,939.3		14,826.6	
Half High	836.0	67.1%	1,065.8	57.6%	2,400.0	54.1%	4,945.5	49.8%	5,924.8	40.0%
Slim	410.0	32.9%	783.0	42.4%	2,040.0	45.9%	4,993.8	50.2%	8,901.8	60.0%
Noncaptive Total	4,460.4		11,503.0		25,649.0		50,383.4		78,005.8	
Half High	4,279.4	95.9%	10,716.5	93.2%	23,677.0	92.3%	45,864.0	91.0%	70,313.6	90.1%
Slim	181.0	4.1%	786.5	6.8%	1,972.0	7.7%	4,519.4	9.0%	7,692.2	9.9%
Total Non-U.S.	5,706.4		13,351.8		30,089.0		60,322.7		92,832.4	
Half High	5,115.4	89.6%	11,782.3	88.2%	26,077.0	86.7%	50,809.5	84.2%	76,238.4	82.1%
Slim	591.0	10.4%	1,569.5	11.8%	4,012.0	13.3%	9,513.2	15.8%	16,594.0	17.9%
WORLDWIDE SHIPMENTS										
Total Shipments	5,706.4		13,351.8		30,089.0		60,322.7		92,832.4	
	+375.9%		+134.0%		+125.4%		+100.5%		+53.9%	
Half High	5,115.4	89.6%	11,782.3	88.2%	26,077.0	86.7%	50,809.5	84.2%	76,238.4	82.1%
	+326.6%		+130.3%		+121.3%		+94.8%		+50.0%	
Slim	591.0	10.4%	1,569.5	11.8%	4,012.0	13.3%	9,513.2	15.8%	16,594.0	17.9%
	--		+165.6%		+155.6%		+137.1%		+74.4%	

Notes: Percentage figures with plus/minus signs refer to year-to-year growth rates.

TABLE 21

DVD-ROM OPTICAL DISK DRIVES

APPLICATIONS SUMMARY
Percentage of Worldwide Shipments

APPLICATION	1998 Estimate Units (000)	1998 Estimate %	2002 Projection Units (000)	2002 Projection %
SPECIALIZED HIGH PERFORMANCE Supercomputers, video and high end imaging	--	--	1,299.7	1.4
MAINFRAME SYSTEMS General purpose	--	--	92.8	.1
NETWORK/MIDRANGE SYSTEMS Midrange systems, network servers and workstations	479.3	8.4	10,768.6	11.6
DESKTOP PERSONAL COMPUTERS Business and professional, single user	4,245.6	74.4	43,538.4	46.9
CONSUMER COMPUTERS Desktop PCs, game, and hobby computers	507.9	8.9	20,423.1	22.0
PORTABLE COMPUTERS Notebook and smaller mobile computers	331.0	5.8	15,595.8	16.8
OTHER APPLICATIONS	142.6	2.5	1,114.0	1.2
Total	5,706.4	100.0	92,832.4	100.0

TABLE 22

DVD-ROM OPTICAL DISK DRIVES

MARKET SHARE SUMMARY
Worldwide Shipments of Noncaptive Disk Drives

1998 Net Shipments

Drive Manufacturers	To United States Destinations Units (000) <=2X	3X-4X	5X-6X	>=8X	Total	%	Worldwide Units (000) <=2X	3X-4X	5X-6X	>=8X	Total	%
Hitachi	622.1	624.9	.1	--	1247.1	46.1	785.9	1182.5	4.0	--	1972.4	44.2
Toshiba	355.0	15.0	405.0	--	775.0	28.7	525.0	25.0	541.0	--	1091.0	24.5
Matsushita Elec.	402.0	70.0	--	--	472.0	17.5	600.0	170.0	--	--	770.0	17.3
Other U.S.	--	--	--	--	--	--	--	--	--	--	--	--
Other Non-U.S.	62.0	130.0	18.0	--	210.0	7.7	263.0	304.0	60.0	--	627.0	14.0
TOTAL	1441.1	839.9	423.1	--	2704.1	100.0	2173.9	1681.5	605.0	--	4460.4	100.0

Note: "<=" means "less than or equal to".
">=" means "greater than or equal to".

CD/DVD FORMAT WRITABLE OPTICAL DISK DRIVES

CD/DVD FORMAT WRITABLE OPTICAL DISK DRIVES

Coverage

Examples of disk drives in this group include:

12 centimeter disk diameter

Acer Peripherals	CRW-4432A (E)
Actima	ARW4420 (E)
AOpen	CRW-9624 (E), DVD-520S (D)
Behavior Tech Computer	BCE 2421E (E), BCE 4424 (C)
Delta Electronics	ODE-6121 (E)
Hewlett-Packard	3100i (D), 8110i (E)
Hitachi	GF-1055 (D)
JVC	XR-W4080 (E), XR-W4424 (E)
Leoptics	CDD-3244 (E)
LG Electronics	CED-8042B (E)
Lite-On	LTR-041 (E)
Matsushita Electric Industrial	CW-7503B (C), LF-1700 (P), LF-D111 (D)
Mitsumi Electric	CR4802TE (E)
NEC	ODX-658 (P)
Pan-International (Cyberdrive)	CD RW 602 (E), CRD-R800SCD (C)
Philips	CD-RW 400 (E), CDD 4201 (E)
Pioneer	DW-S114X (C), DVR-S101 (R)
Plextor	PX-R412CS (C), PX-R820Ti (C)
Ricoh	MP7040A-ED (E), MP8040-SE (E)
Samsung Electronics	SW-208 (E), SR-702 (D)
Sanyo Electric	CRD-R800S (C), CRD-RW1N (E)
Sony	CDU948SC, CRX120E (E), DRX101S (D)
Tatung	CRW-4432E (E)
TEAC	CD-R58S (C), CD-W54E (E)
Toshiba	SD-W1111 (D)
Ultima Electronics (Artec)	Super-RW (E)
Wearnes Peripherals	CDRW-622 (E), CDRW-2444 (E)
Yamaha	CRW6416S (E), CRW4416E (E)

(C) indicates CD-R drive.
(E) indicates CD-RW drive.
(D) indicates DVD rewritable drive
(P) indicates PD drive
(R) indicates DVD-R drive

Drives included in this group use CD-ROM or one of several DVD writable formats, and have the ability to record in either write-once or rewritable mode. This includes CD-R (write-once), CD-RW (rewritable, including combination drives with DVD-ROM capability), DVD-R (write-once), PD (rewritable), DVD-RAM (rewritable), and DVD+RW (designated as PC+RW by the DVD forum, to avoid conflict with "DVD-RAM") and DVD-RW drives when they appear. CD-RW drives can use less expensive write-once media as well as rewritable media. Writable formats intended for audio/video recording are not included. Although the writing format of PD drives is not CD compatible, PD drives do have CD-ROM read capabilities and are included here for convenience. The drives discussed in this section are typically used with personal, consumer and midrange computer systems of the mini and micro class, with intelligent workstations, and with network servers. They are also found in storage subsystems such as jukeboxes, towers and media duplicators.

Market status

Though hampered by shortages of pickups for CD-RW drives, 1998 shipments for this group expanded 79.1% to over 6.1 million units, despite declines in PD drive production. However, 1999 CD-RW drive production is exploding as component shortages ease, prices fall, and pent-up demand is translated into shipments. The group composition is rapidly changing: CD-R is declining, CD-RW is expanding, and combined shipments accounted for 94.4% of 1998 shipments. and will exceed 90% of 1998 and 1999 shipments. Though CD-R drives were in the majority in 1997, CD-RW had the largest 1998 share. Slim form factor CD-RW drives made their appearance in 1999, and will find use in upper end notebook systems. PD drive shipments reached 704,500 units in 1997, but declined rapidly in 1998, with only 229,000 shipped for the year, due to OEM disinterest and displacement by DVD-RAM. DVD-RAM shipments began in earnest in 1998 (Hitachi was the first volume producer), with almost 120,000 shipped for the year and a fourfold expansion underway in 1999. Pioneer is shipping DVD-R drives in low quantities, and availability of DVD+RW drives in the fall of 1999 has been announced.

Shipments of CD-R and CD-RW drives have been strengthened by declining prices, easier integration, and increased use in personal computer systems. An increasing number of companies and individual users now publish, archive, or back up in CD-ROM formats. The CD-R/RW drives can also be used to transmit finished content to testers and CD-ROM replicators. Although shortages of CD-R media occurred in 1996, CD-R and CD-RW media suppliers now have sufficient capacity.

Sales revenues for the group increased 37.4% to over $1.3 billion in 1998. About 43% of unit shipments were made to the U.S., a significant increase from the previous year, reflecting increased interest among OEMs and end users alike in CD-R and CD-RW for backup and individual use recording of internet, audio and video content. Worldwide OEM activity rose to 53.4% of unit shipments, but only 50% of revenues. 39.4% of unit shipments were to distributors, which provided 40.9% of revenues. The balance was derived from captive sales.

Sony, Philips, and Yamaha were the leading CD-R/RW drive producers in 1998, accounting for over 77% of overall unit shipments between them. Hitachi was the leading manufacturer supplying DVD-RAM drives in quantity. Pioneer was first to ship DVD-R, but with a $15,000 drive price and $50 media, the market is limited to serious professional content developers.

Marketing trends

Very strong unit shipment growth is forecast through 2002, with revenues nearly tripling and unit shipments more than quadrupling as component restrictions ease and prices decline. Product mix will continue to change radically as production of CD-RW drives are displaced by DVD-writable drives after 2000 and begin their run to become the expected dominant product. However, until the writable DVD format wars are resolved and 4.7 gigabyte capacity for DVD writable drives (expected in late 2000) is obtained, DVD writable will be a sideshow to the CD-RW main event, capturing only a 24% share of shipments in 2002.

Shipments for the group are expected to exceed 29.8 million units in 2002, while revenues expand to over $3.3 billion. DVD writable formats of all types are expected to account for 24.3% of unit shipments in 2002, while CD-RW drives will hold 75.7% of shipments. Slim form factor drives are projected to account for 12.4% of group shipments in 2002. The major uncertainty is the degree to which DVD-RAM will share the DVD writable segment with other formats. Because DVD-RAM reached production over a year ahead of DVD+RW, it is expected to become well established and remain the dominant DVD writable format, with its major growth beginning in 2000 when 4.7 gigabyte drives and media are anticipated. DVD-R is expected to remain a minor player because of its write-once limitation, high price and limited number of producers.

Applications

CD-R and CD-RW drives are used for short run disk duplication and distribution where volume does not warrant the cost of the replication process, but backup and archiving of files are also significant applications. They are also frequently installed in CD-ROM libraries to automate disk handling when multiple disks must be produced, to reduce manual handling of disks and reduce labor costs. The drives can also be used for audio/video recording, an increasingly popular consumer application. PD drives had their greatest success in Japan, where they were used for backup/restore and data interchange.

Applications for DVD writable formats are not fully defined. Content preparation and video editing/production are viable applications (but 4.7 gigabyte capacity is needed). However, it's unclear which other uses will require the large content of DVD. CD-RW is expected to remain viable for an extended period, as many users will find that CD-RW has sufficient capacity for their distribution needs, and much lower overall costs.

Users of CD-RW drives are able to use either CD-R media or rewritable CD-RW media and can obtain the same storage utility functions currently provided by floppy disk drives or inexpensive tape drives, albeit at a higher price. CD-RW may be preferred over CD-R for routine save/restore uses since the media can be recycled. However, the less expensive CD-R media is preferred for archival and distribution applications. While some producers of CD-RW drives forecast that CD-RW will replace the standard floppy drive on most personal computers, the large price difference between the drives and the convenience and large installed base of floppy drives makes a complete replacement an unlikely event.

Matsushita positioned PD drives as backup, archival and save/restore drives that can also read CD-ROM media. They also have applications in small servers, where their combined capability for archiving, backup and installing CD-ROM based software across a network makes them attractive. PD drives competed ineffectively against CD-RW drives because of their higher prices, even though some PD manufacturers, such as NEC, introduced drives that can read CD media, write once on CD-R media, and perform the rewritable function in PD mode.

Attachments to business personal computers accounted for 67.5% of the units shipped in 1998, but this percentage will decrease to 44.6% in 2002 as usage with consumer systems rises to 24.6%. The share of storage subsystems, servers and workstations will remain in the 11% range. Workstations used to prepare CD-ROMs, Web pages and other graphics content are expected to be major users of drives in this group. Usage in portable systems is expected to reach a 14.2% share in 2002, largely from internal use in notebook systems.

Technical trends

Production shipments of CD-RW drives began in late 1997 and are rapidly displacing CD-R drives, as the CD-RW drive can use either type of media. Shipments of the first production DVD-R drives started in early 1998. Hitachi, first to ship production DVD-RAM drives, also started in the first half of 1998. PD drives are being displaced by DVD-RAM as it enters its ramp-up phase in 1999. Shipments of DVD+RW drives are now expected in late 1999. DVD-RW, sponsored by Pioneer, has an uncertain shipment schedule, but shipment of production units in 2000 is considered likely. Evaluation units may be available in 1999. Some of the key aspects of this product progression are reviewed below:

> Capacity: The per-surface capacity of CD-RW drives is the same as CD-R and CD-ROM. However, due to technical limitations, the capacity of DVD-R is limited to 3.95 gigabytes in its initial form, while DVD-RAM drives are limited to 2.6 gigabytes per side in their initial releases. DVD+RW drives have 3 gigabyte capacity in their initial forms. All of these formats are expected to migrate to 4.7 gigabyte capacity by the end of 2000. Further capacity increases for DVD beyond 4.7 gigabytes will be due to a combination of factors, including improved optics and shorter laser wavelength, permitting smaller spots and higher BPI and TPI.

> Write-once recording: The technology used for CD-R recording is dye-based, while the technology used for CD-RW and DVD-R is phase change. In either method, the writing laser causes a change in media reflectivity that can be sensed during the readback process. Unfortunately, CD-R media was not readable by first generation DVD-ROM or other DVD types because the CD-R media, written with a 780 nanometer laser, is essentially transparent at the shorter 650 nanometer wavelengths used by DVD drives. This problem was resolved by putting dual laser pickups in second generation and later DVD drives.

> Rewritability: Phase change technology is used for PD, DVD rewritable and CD-RW drives, and there is a consortium of disk drive manufacturers working on a magneto-optic drive that will also be able to read CD-ROM

and DVD-ROM media. Availability is very uncertain. Like MO technology, phase change technology permits the interchange of write-once and erasable media on a single drive. It also provides direct overwrite capability with simpler drive designs than for MO drives. However, phase change media has a limitation on the number of possible write/erase cycles, much lower than MO media.

CD-RW media cannot be read by most pre-1997 CD-ROM drives because of differences in media reflectivity, but addition of an inexpensive automatic gain control circuit to many new CD-ROM drive models resolved this incompatibility. Because of format differences, DVD writable media cannot be read by any CD-ROM drives, nor can it be read by DVD-ROM drives produced before the second half of 1998. The 4.7 gigabyte DVD writable format projected for 2000 cannot be read on any existing DVD-ROM drive, though some drives may be able to do so by late 1999.

Average access times: Average access times (seek plus latency) for products in this group are not fast, with 100 to 150 milliseconds being typical This slow performance is one of the motivating factors encouraging the development of the MO drives in 12 centimeter formats, since the typical performance of an MO drive would offer average access times well under 50 milliseconds, a more suitable value for a computer peripheral.

Data transfer rate: Typical CD-RW performance is now 4X write and 24X or 32X read, although 6X and 8X write drives are increasingly available. PD drives have a maximum data transfer rate of 1.41 megabytes per second. DVD-RAM drives typically offer 1X write speeds and 2X read speeds. DVD-writable drives can also read CD format media, usually at speeds of 20X or greater. Write rates will continue to lag, due to laser power and media sensitivity limits.

DVD-RAM drives maintain speed control using zoned CLV, while DVD+RW uses CAV speed control. The CAV design is inherently simpler, and may result in an eventual cost advantage for DVD+RW drive producers. DVD+RW 1X write speeds are also somewhat higher than for DVD-RAM.

Packaging: Most of the drives in this group are packaged in a half height 5.25" form factor, and frequently as externally mounted drives for ease in integration. There is no fundamental reason the drives could not be reduced in height, and demand from notebook computer markets and availability of smaller pickups have stimulated production of slim CD-RW drives. Eventual availability of slim DVD-writable drives is anticipated.

Standards: In mid-1997, the members of the DVD forum agreed upon the specification for DVD-RAM with 2.6 gigabytes, with a final standard subsequently published. A 4.7 gigabyte format standard is expected to be released in late 1999, although a preliminary version has already been widely circulated. The group has also released a standard for DVD-RW, proposed by Pioneer. Whereas the DVD-RAM format is optimized for random access of records, the DVD-RW format is optimized for sequential access and will be of most significance to DVD-ROM content creators.

In mid-1997, a splinter group, which includes Philips, Sony, Ricoh, and Hewlett-Packard, announced that they were supporting a 3 gigabyte capacity version, creating a huge incompatibility problem as DVD rewritable drives come to market. The alternate format, identified as DVD+RW, was submitted to ECMA as a proposed standard. The DVD+RW sponsors indicate that the reason for their action was to produce a drive generating a format closer to that used for DVD-ROM. This action was followed by an announcement from NEC that they would produce 12 centimeter drives with a 5.2 gigabyte capacity (MMVF, or Multi Media Video Format), but not compatible with DVD-RAM. These are intended for AV use, not as computer peripherals. With everyone promoting their own "standards", it remains for prospective purchasers to select the standard they like.

Competing Products: Products in this group face competition from other optical and magnetic removable drives of equivalent or greater capacity. This competition is effective only if CD-ROM or DVD-ROM compatibility is not an issue. 3.5" MO drives, high capacity floppy drives and rigid cartridge disk drives compare reasonably well in price with drives in this group, supplying equivalent or superior capacity and performance in some cases. Where CD/DVD compatibility is an issue, there is no competition except between drives in this group.

A magneto-optic competitor for DVD-RAM is being examined by a group of companies including Fujitsu, Olympus, Philips, Hitachi, Sony, Sanyo, Sharp and Hitachi Maxell. The target drive will have a capacity of 6 gigabytes and performance substantially better than that projected for DVD-RAM using phase change media. The drives are also expected to read CD-ROM and DVD-ROM media, but probably will not read other magneto-optic media formats. The group developed a working specification for the drive and media in 1997, but availability is uncertain.

Competition from advanced magneto-optic drives such as the TeraStor products, assuming that they turn out to be price competitive when introduced, is also anticipated. TeraStor has announced 10 and 20 gigabyte drives and indicated its intention to produce a double sided 40 gigabyte drive, but none of these are judged likely to be in production before mid-1999. Again, these drives can compete only where their format incompatibilities are not disadvantageous.

The most immediate performance competition comes from removable cartridge magnetic disk drives such as the Iomega Jaz drive and the Castlewood ORB, both in the 1-2 gigabyte range, and price competitive, with superior performance. However, because they are not CD format compatible and use expensive media, direct competition is not expected.

Rather, the existence of these and other high performance competitors limits the expansion potential for the CD format products in this group.

Forecasting assumptions

1. CD-RW drive production will not be limited by component shortages after 1999. Media supplies will be adequate.
2. Components for DVD writable drives will be in relatively short supply until after 2000. 4.7 gigabyte DVD-writable drives will start production in 2000.
3. DVD-writable drives will not begin to seriously impact CD-RW production until after 2000. DVD-RAM will be the dominant writable DVD format.
4. Advanced magneto-optic drives will not significantly impact this product group within the forecast period.

TABLE 23

CD/DVD FORMAT WRITABLE OPTICAL DISK DRIVES

REVENUE SUMMARY

	DISK DRIVE REVENUES, BY SHIPMENT DESTINATION ($M)									
	1998 Revenues		Forecast 1999		2000		2001		2002	
	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW
U.S. Manufacturers										
TOTAL U.S. REVENUES	--	--	--	--	--	--	--	--	--	--
Non-U.S. Manufacturers										
Captive	17.0	158.0	44.6	207.3	63.7	278.8	79.4	322.7	95.0	298.0
Distributor	107.4	534.5	350.4	1,069.0	457.6	1,157.7	560.9	1,414.3	658.7	1,608.5
OEM/Integrator	364.3	614.0	362.2	931.5	493.4	1,335.6	518.1	1,443.8	467.9	1,430.5
TOTAL NON-U.S. REVENUES	488.7	1,306.5	757.2	2,207.8	1,014.7	2,772.1	1,158.4	3,180.8	1,221.6	3,337.0
Worldwide Recap										
TOTAL WORLDWIDE REVENUES	488.7	1,306.5	757.2	2,207.8	1,014.7	2,772.1	1,158.4	3,180.8	1,221.6	3,337.0
OEM Average Price ($000)		.188		.158		.133		.113		.100

TABLE 24

CD/DVD FORMAT WRITABLE OPTICAL DISK DRIVES

UNIT SHIPMENT SUMMARY

	DISK DRIVE UNIT SHIPMENTS, BY SHIPMENT DESTINATION (000)									
	1998		Forecast							
	Shipments		1999		2000		2001		2002	
	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW
U.S. Manufacturers										
TOTAL U.S. SHIPMENTS	--	--	--	--	--	--	--	--	--	--
Non-U.S. Manufacturers										
Captive	51.0	442.0	141.8	578.5	227.9	922.5	297.4	1,160.6	367.6	1,268.8
Distributor	515.5	2,407.4	1,973.6	6,116.8	3,172.5	8,057.6	4,562.1	11,594.4	5,860.2	14,317.4
OEM/Integrator	2,069.1	3,265.3	2,303.9	5,878.8	3,768.6	10,016.8	4,640.0	12,686.7	4,814.2	14,219.2
TOTAL NON-U.S. SHIPMENTS	2,635.6	6,114.7	4,419.3	12,574.1	7,169.0	18,996.9	9,499.5	25,441.7	11,042.0	29,805.4
Worldwide Recap										
TOTAL WORLDWIDE SHIPMENTS	2,635.6	6,114.7	4,419.3	12,574.1	7,169.0	18,996.9	9,499.5	25,441.7	11,042.0	29,805.4
Cumulative Shipments (Units in millions)										
WORLDWIDE TOTAL	4.9	11.5	9.4	24.1	16.5	43.1	26.0	68.5	37.1	98.3

TABLE 25

CD/DVD FORMAT WRITABLE OPTICAL DISK DRIVES

WORLDWIDE REVENUES ($M)

BREAKDOWN BY DRIVE TYPE

	1998 Revenues				Forecast 1999				2000				2001			2002	
	CD-R	CD-RW	DVD	PD	CD-R	CD-RW	DVD	PD	CD-R	CD-RW	DVD	PD	CD-R	CD-RW	DVD	CD-RW	DVD
U.S. MANUFACTURERS																	
TOTAL U.S. REVENUES	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
NON-U.S. MANUFACTURERS																	
Captive	13.2	59.5	41.9	43.4	4.6	90.9	107.0	4.8	.6	131.5	146.3	.4	--	149.1	173.6	147.1	150.9
Distributor	251.4	252.1	22.3	8.7	153.5	822.5	93.0	--	50.4	964.2	143.1	--	4.3	1,054.9	355.1	860.1	748.4
OEM/Integrator	62.5	524.9	12.4	14.2	79.8	816.5	32.3	2.9	24.3	1,240.5	70.8	--	4.0	1,351.1	88.7	1,190.7	239.8
TOTAL NON-U.S. REVENUES	327.1	836.5	76.6	66.3	237.9	1,729.9	232.3	7.7	75.3	2,336.2	360.2	.4	8.3	2,555.1	617.4	2,197.9	1,139.1
WORLDWIDE RECAP																	
Captive	13.2	59.5	41.9	43.4	4.6	90.9	107.0	4.8	.6	131.5	146.3	.4	--	149.1	173.6	147.1	150.9
	+560.0%	--	--	-70.6%	-65.2%	+52.8%	+155.4%	-88.9%	-87.0%	+44.7%	+36.7%	-91.7%	--	+13.4%	+18.7%	-1.3%	-13.1%
Distributor	251.4	252.1	22.3	8.7	153.5	822.5	93.0	--	50.4	964.2	143.1	--	4.3	1,054.9	355.1	860.1	748.4
	+12.0%	+75.6%	+431.0%	-90.5%	-38.9%	+226.3%	+317.0%	--	-67.2%	+17.2%	+53.9%	--	-91.5%	+9.4%	+148.1%	-18.5%	+110.8%
OEM/Integrator	62.5	524.9	12.4	14.2	79.8	816.5	32.3	2.9	24.3	1,240.5	70.8	--	4.0	1,351.1	88.7	1,190.7	239.8
	-72.3%	+569.5%	--	-57.4%	+27.7%	+55.6%	+160.5%	-79.6%	-69.5%	+51.9%	+119.2%	--	-83.5%	+8.9%	+25.3%	-11.9%	+170.3%
Total Revenues	327.1	836.5	76.6	66.3	237.9	1,729.9	232.3	7.7	75.3	2,336.2	360.2	.4	8.3	2,555.1	617.4	2,197.9	1,139.1
	-27.6%	+276.8%	--	-75.7%	-27.3%	+106.8%	+203.3%	-88.4%	-68.3%	+35.0%	+55.1%	-94.8%	-89.0%	+9.4%	+71.4%	-14.0%	+84.5%
ANNUAL SHARE, BY DIAMETER	25.1%	64.0%	5.9%	5.0%	10.8%	78.5%	10.5%	.2%	2.7%	84.4%	12.9%	--	.3%	80.4%	19.3%	66.0%	34.0%

Note: DVD includes DVD-RAM, DVD+RW and all other DVD writable formats.

TABLE 26

CD/DVD FORMAT WRITABLE OPTICAL DISK DRIVES

WORLDWIDE SHIPMENTS (000)

BREAKDOWN BY DRIVE TYPE

	1998 Shipments				Forecast 1999				Forecast 2000				Forecast 2001			Forecast 2002	
	CD-R	CD-RW	DVD	PD	CD-R	CD-RW	DVD	PD	CD-R	CD-RW	DVD	PD	CD-R	CD-RW	DVD	CD-RW	DVD
U.S. MANUFACTURERS																	
TOTAL U.S. SHIPMENTS	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
NON-U.S. MANUFACTURERS																	
Captive	60.0	202.0	56.0	124.0	24.3	362.3	178.2	13.7	3.6	625.3	292.4	1.2	--	783.3	377.3	881.7	387.1
Distributor	1,287.0	1,041.0	36.4	43.0	925.3	4,926.9	264.6	--	311.4	7,195.5	550.7	--	28.9	9,705.6	1,859.9	9,099.9	5,217.5
OEM/Integrator	314.0	2,862.0	27.3	62.0	559.4	5,205.9	102.1	11.4	188.5	9,518.7	309.6	--	35.4	12,147.1	504.2	12,543.7	1,675.5
TOTAL NON-U.S. SHIPMENTS	1,661.0	4,105.0	119.7	229.0	1,509.0	10,495.1	544.9	25.1	503.5	17,339.5	1,152.7	1.2	64.3	22,636.0	2,741.4	22,525.3	7,280.1
WORLDWIDE RECAP																	
Captive	60.0	202.0	56.0	124.0	24.3	362.3	178.2	13.7	3.6	625.3	292.4	1.2	--	783.3	377.3	881.7	387.1
	+500.0%	--	--	-58.9%	-59.5%	+79.4%	+218.2%	-89.0%	-85.2%	+72.6%	+64.1%	-91.2%	--	+25.3%	+29.0%	+12.6%	+2.6%
Distributor	1,287.0	1,041.0	36.4	43.0	925.3	4,926.9	264.6	--	311.4	7,195.5	550.7	--	28.9	9,705.6	1,859.9	9,099.9	5,217.5
	+60.6%	+119.9%	--	-84.0%	-28.1%	+373.3%	+626.9%	--	-66.3%	+46.0%	+108.1%	--	-90.7%	+34.9%	+237.7%	-6.2%	+180.5%
OEM/Integrator	314.0	2,862.0	27.3	62.0	559.4	5,205.9	102.1	11.4	188.5	9,518.7	309.6	--	35.4	12,147.1	504.2	12,543.7	1,675.5
	-69.9%	+651.2%	--	-53.4%	+78.2%	+81.9%	+274.0%	-81.6%	-66.3%	+82.8%	+203.2%	--	-81.2%	+27.6%	+62.9%	+3.3%	+232.3%
Total Shipments	1,661.0	4,105.0	119.7	229.0	1,509.0	10,495.1	544.9	25.1	503.5	17,339.5	1,152.7	1.2	64.3	22,636.0	2,741.4	22,525.3	7,280.1
	-10.4%	+380.4%	--	-67.5%	-9.2%	+155.7%	+355.2%	-89.0%	-66.6%	+65.2%	+111.5%	-95.2%	-87.2%	+30.5%	+137.8%	-.5%	+165.6%
ANNUAL SHARE, BY DIAMETER	27.3%	67.1%	2.0%	3.6%	12.0%	83.6%	4.3%	.1%	2.7%	91.4%	5.9%	--	.3%	89.1%	10.6%	75.7%	24.3%

Note: DVD includes DVD-RAM, DVD+RW and all other DVD writable formats.

TABLE 27

CD/DVD FORMAT WRITABLE OPTICAL DISK DRIVES

WORLDWIDE SHIPMENTS (000)

DRIVE HEIGHT ANALYSIS

	1998 --Shipments-- Units	%	Forecast -----1999---- Units	%	-----2000---- Units	%	-----2001---- Units	%	-----2002---- Units	%
U.S. MANUFACTURERS										
Total U.S.	--		--		--		--		--	
NON-U.S. MANUFACTURERS										
Captive Total	442.0		578.5		922.5		1,160.6		1,268.8	
Half High	442.0	100.0%	578.5	100.0%	803.2	87.1%	990.3	85.3%	1,007.2	79.4%
Slim	--	--	--	--	119.3	12.9%	170.3	14.7%	261.6	20.6%
Noncaptive Total	5,672.7		11,995.6		18,074.4		24,281.1		28,536.6	
Half High	5,672.7	100.0%	11,456.1	95.5%	16,784.5	92.9%	22,076.7	90.9%	25,099.1	88.0%
Slim	--	--	539.5	4.5%	1,289.9	7.1%	2,204.4	9.1%	3,437.5	12.0%
Total Non-U.S.	6,114.7		12,574.1		18,996.9		25,441.7		29,805.4	
Half High	6,114.7	100.0%	12,034.6	95.7%	17,587.7	92.6%	23,067.0	90.7%	26,106.3	87.6%
Slim	--	--	539.5	4.3%	1,409.2	7.4%	2,374.7	9.3%	3,699.1	12.4%
WORLDWIDE SHIPMENTS										
Total Shipments	6,114.7		12,574.1		18,996.9		25,441.7		29,805.4	
	+79.1%		+105.6%		+51.1%		+33.9%		+17.2%	
Half High	6,114.7	100.0%	12,034.6	95.7%	17,587.7	92.6%	23,067.0	90.7%	26,106.3	87.6%
	+79.1%		+96.8%		+46.1%		+31.2%		+13.2%	
Slim	--	--	539.5	4.3%	1,409.2	7.4%	2,374.7	9.3%	3,699.1	12.4%
	--		--		+161.2%		+68.5%		+55.8%	

Notes: Percentage figures with plus/minus signs refer to year-to-year growth rates.

TABLE 28

CD/DVD FORMAT WRITABLE OPTICAL DISK DRIVES

APPLICATIONS SUMMARY
Percentage of Worldwide Shipments

APPLICATION	1998 Estimate Units (000)	1998 Estimate %	2002 Projection Units (000)	2002 Projection %
SPECIALIZED HIGH PERFORMANCE Supercomputers, video and high end imaging	36.7	.6	1,311.4	4.4
MAINFRAME SYSTEMS General purpose	--	--	59.6	.2
NETWORK/MIDRANGE SYSTEMS Midrange systems, network servers and workstations	709.3	11.6	3,308.4	11.1
DESKTOP PERSONAL COMPUTERS Business and professional, single user	4,127.4	67.5	13,293.2	44.6
CONSUMER COMPUTERS Desktop PCs, game, and hobby computers	623.7	10.2	7,332.1	24.6
PORTABLE COMPUTERS Notebook and smaller mobile computers	18.3	.3	4,232.4	14.2
OTHER APPLICATIONS	599.3	9.8	268.3	.9
Total	6,114.7	100.0	29,805.4	100.0

TABLE 29

CD/DVD FORMAT WRITABLE OPTICAL DISK DRIVES

MARKET SHARE SUMMARY
Worldwide Shipments of Noncaptive Disk Drives

1998 Net Shipments

	To United States Destinations						Worldwide					
	Units (000)					%	Units (000)					%
Drive Manufacturers	CD-R	CD-RW	DVD	PD	Total		CD-R	CD-RW	DVD	PD	Total	
Sony	--	876.0	--	--	876.0	33.9	--	1488.0	--	--	1488.0	26.2
Philips	--	1110.0	--	--	1110.0	42.9	--	1390.0	--	--	1390.0	24.5
Yamaha	23.0	140.0	--	--	163.0	6.3	123.0	804.0	--	--	927.0	16.3
TEAC	98.0	--	--	--	98.0	3.8	688.0	--	--	33.0	721.0	12.7
Other U.S.	--	--	--	--	--	--	--	--	--	--	--	--
Other Non-U.S.	245.0	75.3	17.3	--	337.6	13.1	790.0	221.0	63.7	72.0	1146.7	20.3
TOTAL	366.0	2201.3	17.3	--	2584.6	100.0	1601.0	3903.0	63.7	105.0	5672.7	100.0

Note: DVD includes all writable DVD formats.

READ/WRITE OPTICAL DISK DRIVES, LESS THAN 4 GIGABYTES

READ/WRITE OPTICAL DISK DRIVES LESS THAN 4 GIGABYTES

Coverage

Examples of disk drives in this group include:

3.5" disk diameter

Fujitsu	M2513A, M2541B, MC3064SS
Konica	OMD-9060, OMD-9062
Olympus	640MO Turbo, MOS330E, MOS350E

5.25" disk diameter

Hitachi	OD172, OL-F172S
Maxoptix	T5-2600, T6-5200
Mountain Optech	CS-5200, ST-5200
NEC	N1137-57, ODD-160
Pinnacle Micro	Apex
Pioneer	DE-SH9101, DE-SH2200
Sony	RMO-S594, SMO-F551, RMO-S591

This product group includes two types of optical disk drives: Write Once Read Many, (WORM) and Rewritable. Multifunction drives capable of using either rewritable or write-once media are considered rewritable drives for purposes of this report. This includes MO multifunction drives (MO-WORM or Continuous Composite WORM), certain phase change drives, and multifunction magneto-optic/ablative media drives. No WORM drives in this group are currently in volume production.

The read/write drives in this section are typically used with small and mid-range computers of the mini and micro class and with workstations. Automated optical libraries (jukeboxes, in industry parlance) used in mass storage subsystems are usually equipped with 5.25" read/write drives.

Market status

3.5" drive shipments rose 20.8% in 1998, while shipments of 5.25" drives again declined, producing combined growth of 17.1% in unit shipments for the product group. 3.5" drive shipments rose to over 1.7 million units. Shipments of 5.25" drives declined to 115,200 units. However, only a few producers of 3.5" drives remain active, and the ranks of companies actively manufacturing 5.25" drives in this group shrank further as Olympus and Nikon opted out.

1998 shipments of 3.5" drives through distribution remained high, at over 77% of the worldwide total. Their strength with Japanese distributors and integrators is the major factor influencing the small share of 3.5" drive shipments into the U.S., less than 6% of the worldwide total. The Apple Macintosh add-on market, with less price sensitivity, remains the healthiest 3.5" market segment in the U.S., although Fujitsu has had some recent success with workstation OEMs. Fujitsu was the leading 1998 noncaptive producer of 3.5" drives, (followed by Olympus), again producing more than all other manufacturers combined.

Sony repeated as the leading noncaptive producer of 5.25" drives in 1998. No other producer came even close, confirming Sony's very strong position for the time being. All 3.5" drive producers are Japanese firms, but about 18% of 1998 5.25" drive production was done by U.S. firms.

Worldwide sales revenues rose 3.5% to $611 million in 1998. Minor price declines allowed 3.5" drive revenues to rise 15.7%, while 5.25" drive revenues dropped 20.9%. U.S. firms accounted for 16.4% of 1998 sales revenues. Further price declines may be minimal due to the decreasing number of competitors and the anticipated phase in of 1.3 gigabyte 3.5" MO drives at higher prices later in 1999.

Marketing trends

Rewritable 5.25" drives with capacities of over two gigabytes per side are now standard, but this isn't enough to reverse the downward trend in shipments of 5.25" drives in this product group. Competition from tape drives, magnetic disk drives, with both fixed and removable disks, offering low OEM and distribution pricing during future years, will continue to contribute to the decline. Optical libraries have become increasingly significant users of 5.25" drives, and this application has been capped by the greater success of tape libraries. 5.25" MO drives with capacities in excess of 4 gigabytes will probably begin shipping in 1999, but in this product group they will remain a dying product line.

3.5" drives with capacities of 640 megabytes are now in production at several companies and capacities in the 1.3 gigabyte range are anticipated by late 1999.

However, the 3.5" MO drive is already challenged by the Castlewood and Iomega families of 3.5" removable rigid disk cartridge gigabyte-plus drives, which offer higher capacity, very competitive prices and superior performance. These drives are very strong competitors in the U.S. market, though less so in Japan where 3.5" MO drives are strongest. The PD drive, the CD-RW drive, and now the DVD-writable drive, will also compete in the same capacity segment of the market, often with lower prices but also with inferior performance. As Japan becomes increasingly networked, the role of the 3.5" MO drive as a data interchange medium is expected to decline. Competition from alternative technologies is expected to cause 3.5" MO drive shipments to peak in 1999 and then subsequently decline.

Shipments for the entire product group are expected to peak in 1999 at 1.98 million drives and decline slightly to 1.9 million in 2000. A further decline to 1.3 million units, almost entirely 3.5" drives, is anticipated in 2002. Sales revenues for the group peaked in 1998 at over $611 million, and are projected to decline to $356 million in 2002.

Applications

5.25" optical drives under 4 gigabytes are used primarily to store images in office, medical, design, video editing, security and other specialized systems. When used as an element of an optical library, the 5.25" drive may provide a second tier storage capability in a hierarchical storage subsystem. There is interest in optical library subsystems operating with hierarchical storage management software for use in network attached data and video servers, but tape's lower cost per stored megabyte has limited the penetration of optical libraries to applications where response time is more crucial than cost per megabyte.

The information management functions of many larger organizations are more likely to prefer write-once storage because of its archival nature and perceived greater security. Smaller organizations or individual work groups in large organizations are more likely to prefer rewritable drives and media for the flexibility and ease of storage management they provide. The ability of some 5.25" multifunction drives to use either rewritable or write-once media largely meets this need.

Despite recent gains in capacity and performance for optical drives, limitations in performance, packaging, power dissipation and price relative to faster improving rigid magnetic disk drives cause optical drives to compete poorly against rigid drives, unless a combination of high capacity and removability are mandatory. Even so, recent retail prices of 4.3 gigabyte rigid drives approximates the pricing of some 5.25" MO media.

The faster erasable drives, such as the Maxoptix "T" series, have found limited application as system disks in high security applications requiring vault storage of recorded media when the equipment is unattended. They are also used as a project storage disk in video editing applications, but this usage has been impacted by the availability of high capacity rigid disk cartridge drives.

3.5" drives are used to provide project oriented storage on a single volume, and are often used to store downloaded Internet files. They also find use in desktop publishing environments where they are used to transfer large amounts of data needed for prepress processing. In Asia, they are frequently used for general purpose data transfer between systems. They have established a role as add-on devices to Apple Macintosh systems, which are frequently used for desktop publishing. The recent price declines and capacity increases may also encourage their use as high performance backup devices for workstations and personal computers.

Desktop personal computers again were the largest application platform for this product group in 1998, accounting for 68.3% of the units shipped. Consumer systems accounted for an additional 15.5%. The share attached to networks and workstations will decline as user interest shifts to higher capacity drives in the over 4 gigabyte range, resulting in share increases for consumer computer and portable system attachment rates. Gigabyte 3.5" drives, when they appear, are expected to receive moderate acceptance in the workstation market, provided they are properly priced.

Technical trends

The technology of optical drives continues to advance, although it is proving difficult for the industry to match the average 60% per year growth rate in areal density exhibited by the rigid disk drive industry. In any event, the next generation of 5.25" optical drives will have capacities high enough to remove them from this product group. While 3.5" drives will continue in the group for the foreseeable future, spinoffs of technology from very high capacity 5.25" designs are expected to eventually "promote" 3.5" drives to the next capacity group.

Capacity: The capacity of 5.25" rewritable drives has reached 2.6 gigabytes per side and is expected to go well beyond that in 1999 when advanced MO drives go into production as projected. The increases will be due to a combination of factors, including improved optics and shorter laser wavelength (permitting smaller spots and higher BPI and TPI), servo improvements permitting reduction of track pitch, the adoption of pulse width modulation, zoned recording, land and groove recording, and variable track pitch. If blue or green semiconductor lasers with adequate power become commercially available, small optical drives will be able to provide several gigabytes of capacity in a 3.5" form factor. With 3.5" drive producers encouraged by the growth in shipments, 1.3 gigabyte 3.5" drives are expected to be developed and shipping by late 1999, though major shipments will probably begin in 2000. A migration of the new high capacity MO technologies (such as near field recording) to 3.5" form factors would result in the availability of 3.5" MO drives and media with capacities of 5 gigabytes or more, though no company has yet projected a specific timetable for availability.

The blue or violet semiconductor lasers that many designers believe hold the key to improving optical storage areal density are available as samples this year, notably from Nichiya Chemical. While the lasers are operable at room temperatures, lifetime and power level may still be an issue.

Write-once recording: A variety of optical recording technologies and media fabrication processes were originally used, creating interchange problems and confusion. Pit forming writing (IBM) and writing using the phase change between amorphous and crystalline states to vary reflectivity at a spot (Matsushita) were the most commonly used methods. Write-once dye-based media was used by Pioneer. In general, media using these separate recording methods are not interchangeable.

Because of the interchange problems, these methods have been displaced by the MO based CCW (Continuous Composite Worm) format, a form of magneto-optic media which 5.25" drives can recognize and treat as write-once media by virtue of a prestamped pattern on the disk. This approach has the benefit of allowing erasable drives capable of recognizing the pattern to operate as multifunction drives. It has gradually become the dominant form of write-once recording on 5.25" drives in this product group. Sony is also marketing a multifunction drive, similar to one once made by IBM, that is capable of using write-once media.

Rewritability: Of the several technologies contending acceptance, magneto-optic media is the most commonly used method capable of meeting user demands for sensitivity, rewritability, and stability. Technical problems and uncertainty about adequate yields for the complex media structures delayed wide use of direct MO overwrite until 1996, when MOST, Nikon and Hitachi began offering 5.25" drives using light intensity modulation to provide direct overwrite capability, but media for those drives has been expensive and scarce.

Multifunctionality can also be achieved on magneto-optic media by designating some portion of the media as write-once or read-only. A group of 14 drive and media producers, including Hewlett-Packard, Maxoptix, Ricoh, and Sony jointly proposed a de facto standard for adding write-once functionality to magneto-optic media. This has been embodied in ISO standard 11560.

Media lifetime: Accelerated life tests indicate that media lifetimes of 10 years or more are achievable, and this aspect of media performance is generally accepted. Some suppliers are claiming in excess of 30 year lifetimes, but archivists remain concerned about media lifetime and whether future generations of drives will be compatible with today's media and recording formats. Given the rapid rate of change in the data storage industry, the latter issue is probably the greater concern

Substrates: Plastic is the currently preferred material, in order to reduce media cost and improve manufacturability. At present, polycarbonate appears to remain the plastic material of choice because of its relative stability and moisture resistance, although tight process control is required to minimize birefringence distortion.

Glass substrates are free of birefringence effects that distort the optical path, are nonpermeable to moisture, are flat, and distortion free. The flat glass surface, coupled with high purity materials, reduces defect levels, which has the advantage of reducing overall latency in the drive due to the reduced need to perform error correction during data reads. Glass also is less likely to deform at high spin rates, reducing runout and servo tracking difficulties. However, glass is denser than plastic, resulting in longer spin-up and spin-down times, a disadvantage when used in optical libraries. Glass is also more costly than plastic substrates.

Average access times: A major limitation of optical drives is average access time (seek time plus latency), which exceeds 40 milliseconds on most 5.25" drives so far announced. With the use of split optics, performance is improved. MO drives are now available with sub-30 millisecond seek times, while the Maxoptix T6-5200 offers a seek time below 20 milliseconds. Newer 3.5" optical disk drives typically have average access times below 40 milliseconds due to their smaller size and shorter stroke lengths, with Olympus and Fujitsu going under the 30 millisecond level. Increasing rotational speed also improves performance. Some Maxoptix drives rotate at over 3,800 RPM, and some 3.5" drives can reach 4,000 RPM rotation rates.

Long access times for optical drives are less significant when the drive is used in an automated library, as the disk exchange and drive spin-up times are lengthy in comparison to the drive average access time. Reduction of drive spin-up time is important when the drive is used in a library-based system in order to minimize the length of the waiting-for-access queue. Spin-up times of 2 seconds or less are desirable. Plastic substrates have less mass than do glass substrates, so are preferable to minimize spin-up time, but are less likely to match glass for long archival life.

Erasable media requires slightly less write power than write-once media, an advantage which can be translated into higher rotation speeds for erasable drives. RPM has increased to 3,000-3,600 RPM for newer drive designs. Maxoptix, Pinnacle Micro and NEC also have offered drives with RPM exceeding 3,600 RPM.

<u>Data transfer rate</u>: Specified internal drive maximum data transfer rates are over 4 megabytes per second range for 5.25" drives and over 3 megabytes per second for 3.5" drives, and are expected to increase as bit density and spin rate increase. The average data transfer rate will be lower, since bit density varies from track to track.

<u>Error rate</u>: Error correcting codes are used to compensate for the high raw error rate of optical media, and are designed to deal with the higher defect density occurring at the end of media life. Although disk data capacity is reduced to accommodate the redundancy needed by ECC methods, the loss may be as little as 8%, depending upon the ECC technique used. Where media have a high defect density, especially if the defects are large, the error correction process can add substantial latency to data retrieval times. Drives will ultimately use more sophisticated ECC circuitry capable of doing on-the-fly error correction so quickly that ECC latency will not be observed, but there will always be a tradeoff between performance and the size of the error correction block.

<u>Packaging</u>: Optical disk drives using read/write 5.25" disks were originally packaged to conform with the envelope of a full height 5.25" floppy disk drive, limiting use to external mounting with many personal computers. More recent drives use the half-height 5.25" form factor, which is now the standard profile.

Fujitsu was the first company to announce and ship a 25.4 mm high 3.5" optical disk drive, followed by a 17 millimeter drive in late 1995 which is still the thinnest available. 25.4 millimeter height is now standard for 3.5" MO drives.

<u>Standards</u>: Standards exist for 3.5" and 5.25" drives and media currently in production. While standards were a contentious issue in the early days of optical recording, the few surviving companies have largely rallied around the road maps established by OSTA, the Optical Storage Technol-

ogy Association, to establish a commonly supported set of goals and timelines. Standards development activity now tends to track the OSTA road map capacity points.

Software: Read/write optical disk drives require specific supporting software, including drivers, operating system utilities, and applications. Basic software must address problems presented by the nature of the optical disk drive:

- Write-once disks require nonstandard file management utilities and drivers. File updates may result in degraded performance if files and directories are dispersed across the disk.
- Magneto-optical disks require modified system software to handle the overwrite requirement, or must have this function performed by the disk electronics or controller.
- File management functions in the computer operating system must be modified so that the optical disk appears to the operating system to be identical to a magnetic disk drive. Most MO optical drives have SCSI interfaces and can use readily available SCSI controllers and drivers that can be managed by the operating system.

Competing products: Strong competition for the 3.5" drives is provided by a range of products, including gigabyte range rigid magnetic disk cartridge drives being delivered by Iomega and Castlewood at prices under current prices for 3.5" MO drives. Fixed magnetic drives with multigigabyte capacities are often advertised at retail prices in the $200 range.

Current 3.5" magnetic rigid disk drives with capacities up to 50 gigabytes have impacted 5.25" optical disk drive sales in applications where a removable disk is not mandatory, and 3.5" magnetic disk drives with capacities exceeding 20 gigabytes are having a restraining effect on MO drive sales as well.

Ultimately, the competing products most impacting this product group are the higher capacity 5.25" optical disk drives that are expected to begin shipments in 1999, and which are discussed in the following product group.

Forecasting assumptions

1. 5.25" optical disk drives with over 4 gigabytes of capacity per side will divert shipments of 5.25" optical drives from this product group beginning in 1999.
2. Components and media will be available in adequate production quantities throughout the forecast period.

3. 600+ megabyte 3.5" optical disk drives will remain in production from multiple major producers throughout the forecast period. 1.3 gigabyte drives are expected to be in production in 1999. The impact of new MO technologies will have a beneficial impact on 3.5" drives in this product group, but the timing is too uncertain for the effects to be forecast.
4. No significant new applications for products in this group are expected to appear during the forecast period.

TABLE 30

READ/WRITE OPTICAL DISK DRIVES, LESS THAN 4 GIGABYTES

REVENUE SUMMARY

	DISK DRIVE REVENUES, BY SHIPMENT DESTINATION ($M)									
	1998 Revenues		Forecast 1999		2000		2001		2002	
	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW
U.S. Manufacturers										
Distributor	8.0	10.6	4.8	6.9	3.8	5.7	3.3	4.6	2.8	3.9
OEM/Integrator	11.2	15.1	10.2	14.3	8.5	11.9	5.4	8.1	3.5	5.5
TOTAL U.S. NONCAPTIVE	19.2	25.7	15.0	21.2	12.3	17.6	8.7	12.7	6.3	9.4
TOTAL U.S. REVENUES	19.2	25.7	15.0	21.2	12.3	17.6	8.7	12.7	6.3	9.4
Non-U.S. Manufacturers										
Captive	6.6	32.5	4.2	22.9	2.9	16.5	1.0	12.2	--	8.4
Distributor	37.3	398.8	41.6	414.9	37.4	402.7	28.2	340.2	22.0	257.8
OEM/Integrator	36.9	154.5	27.5	147.3	20.0	132.2	10.2	99.1	6.2	80.6
TOTAL NON-U.S. REVENUES	80.8	585.8	73.3	585.1	60.3	551.4	39.4	451.5	28.2	346.8
Worldwide Recap										
TOTAL WORLDWIDE REVENUES	100.0	611.5	88.3	606.3	72.6	569.0	48.1	464.2	34.5	356.2
OEM Average Price ($000)		.400		.362		.331		.287		.262

TABLE 31

READ/WRITE OPTICAL DISK DRIVES, LESS THAN 4 GIGABYTES

UNIT SHIPMENT SUMMARY

	DISK DRIVE UNIT SHIPMENTS, BY SHIPMENT DESTINATION (000)									
	1998 Shipments		Forecast							
			1999		2000		2001		2002	
	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW
U.S. Manufacturers										
Distributor	8.0	10.6	5.0	7.2	4.0	6.0	3.0	4.2	2.0	2.8
OEM/Integrator	12.5	16.8	12.0	16.8	10.0	14.0	6.0	9.0	3.5	5.5
TOTAL U.S. NONCAPTIVE	20.5	27.4	17.0	24.0	14.0	20.0	9.0	13.2	5.5	8.3
TOTAL U.S. SHIPMENTS	20.5	27.4	17.0	24.0	14.0	20.0	9.0	13.2	5.5	8.3
Non-U.S. Manufacturers										
Captive	3.0	50.7	2.0	43.8	1.5	37.5	.5	32.2	--	27.0
Distributor	93.5	1,335.3	125.2	1,478.3	117.0	1,430.0	93.0	1,197.0	81.0	982.5
OEM/Integrator	38.0	406.8	35.5	429.5	31.0	421.0	21.0	364.0	15.0	322.0
TOTAL NON-U.S. SHIPMENTS	134.5	1,792.8	162.7	1,951.6	149.5	1,888.5	114.5	1,593.2	96.0	1,331.5
Worldwide Recap										
TOTAL WORLDWIDE SHIPMENTS	155.0	1,820.2	179.7	1,975.6	163.5	1,908.5	123.5	1,606.4	101.5	1,339.8
Cumulative Shipments (Units in millions)										
WORLDWIDE TOTAL	1.7	7.5	1.8	9.4	2.0	11.4	2.1	13.0	2.2	14.3

TABLE 32

READ/WRITE OPTICAL DISK DRIVES, LESS THAN 4 GIGABYTES

WORLDWIDE REVENUES ($M)

BREAKDOWN BY DISK DIAMETER

	1998 Revenues		Forecast 1999		Forecast 2000		Forecast 2001		Forecast 2002	
	5.25"	3.5"	5.25"	3.5"	5.25"	3.5"	5.25"	3.5"	5.25"	3.5"
U.S. MANUFACTURERS										
Distributor	10.6	--	6.9	--	5.7	--	4.6	--	3.9	--
OEM/Integrator	15.1	--	14.3	--	11.9	--	8.1	--	5.5	--
TOTAL U.S. REVENUES	25.7	--	21.2	--	17.6	--	12.7	--	9.4	--
NON-U.S. MANUFACTURERS										
Captive	16.2	16.3	9.6	13.3	4.9	11.6	2.3	9.9	--	8.4
Distributor	29.4	369.4	27.8	387.1	22.0	380.7	7.0	333.2	3.0	254.8
OEM/Integrator	81.4	73.1	71.6	75.7	49.5	82.7	20.0	79.1	12.0	68.6
TOTAL NON-U.S. REVENUES	127.0	458.8	109.0	476.1	76.4	475.0	29.3	422.2	15.0	331.8
WORLDWIDE RECAP										
Captive	16.2	16.3	9.6	13.3	4.9	11.6	2.3	9.9	--	8.4
	-57.0%	-31.8%	-40.7%	-18.4%	-49.0%	-12.8%	-53.1%	-14.7%	--	-15.2%
Distributor	40.0	369.4	34.7	387.1	27.7	380.7	11.6	333.2	6.9	254.8
	-26.6%	+22.8%	-13.2%	+4.8%	-20.2%	-1.7%	-58.1%	-12.5%	-40.5%	-23.5%
OEM/Integrator	96.5	73.1	85.9	75.7	61.4	82.7	28.1	79.1	17.5	68.6
	-4.3%	+1.5%	-11.0%	+3.6%	-28.5%	+9.2%	-54.2%	-4.4%	-37.7%	-13.3%
Total Revenues	152.7	458.8	130.2	476.1	94.0	475.0	42.0	422.2	24.4	331.8
	-20.9%	+15.7%	-14.7%	+3.8%	-27.8%	-.2%	-55.3%	-11.1%	-41.9%	-21.4%
ANNUAL SHARE, BY DIAMETER	25.0%	75.0%	21.5%	78.5%	16.5%	83.5%	9.0%	91.0%	6.9%	93.1%

TABLE 33

READ/WRITE OPTICAL DISK DRIVES, LESS THAN 4 GIGABYTES

WORLDWIDE SHIPMENTS (000)

BREAKDOWN BY DISK DIAMETER

	1998 Shipments		Forecast 1999		Forecast 2000		Forecast 2001		Forecast 2002	
	5.25"	3.5"	5.25"	3.5"	5.25"	3.5"	5.25"	3.5"	5.25"	3.5"
U.S. MANUFACTURERS										
Distributor	10.6	--	7.2	--	6.0	--	4.2	--	2.8	--
OEM/Integrator	16.8	--	16.8	--	14.0	--	9.0	--	5.5	--
TOTAL U.S. SHIPMENTS	27.4	--	24.0	--	20.0	--	13.2	--	8.3	--
NON-U.S. MANUFACTURERS										
Captive	7.7	43.0	4.8	39.0	2.5	35.0	1.2	31.0	--	27.0
Distributor	21.3	1,314.0	22.3	1,456.0	20.0	1,410.0	7.0	1,190.0	2.5	980.0
OEM/Integrator	58.8	348.0	58.5	371.0	45.0	376.0	20.0	344.0	10.0	312.0
TOTAL NON-U.S. SHIPMENTS	87.8	1,705.0	85.6	1,866.0	67.5	1,821.0	28.2	1,565.0	12.5	1,319.0
WORLDWIDE RECAP										
Captive	7.7	43.0	4.8	39.0	2.5	35.0	1.2	31.0	--	27.0
	-56.2%	-18.9%	-37.7%	-9.3%	-47.9%	-10.3%	-52.0%	-11.4%	--	-12.9%
Distributor	31.9	1,314.0	29.5	1,456.0	26.0	1,410.0	11.2	1,190.0	5.3	980.0
	-21.0%	+29.1%	-7.5%	+10.8%	-11.9%	-3.2%	-56.9%	-15.6%	-52.7%	-17.6%
OEM/Integrator	75.6	348.0	75.3	371.0	59.0	376.0	29.0	344.0	15.5	312.0
	-11.7%	+2.4%	-.4%	+6.6%	-21.6%	+1.3%	-50.8%	-8.5%	-46.6%	-9.3%
Total Shipments	115.2	1,705.0	109.6	1,866.0	87.5	1,821.0	41.4	1,565.0	20.8	1,319.0
	-19.8%	+20.8%	-4.9%	+9.4%	-20.2%	-2.4%	-52.7%	-14.1%	-49.8%	-15.7%
ANNUAL SHARE, BY DIAMETER	6.3%	93.7%	5.5%	94.5%	4.6%	95.4%	2.6%	97.4%	1.6%	98.4%

TABLE 34

READ/WRITE OPTICAL DISK DRIVES, LESS THAN 4 GIGABYTES

APPLICATIONS SUMMARY
Percentage of Worldwide Shipments

APPLICATION	1998 Estimate Units (000)	1998 Estimate %	2002 Projection Units (000)	2002 Projection %
SPECIALIZED HIGH PERFORMANCE Supercomputers, video and high end imaging	41.9	2.3	10.7	.8
MAINFRAME SYSTEMS General purpose	10.9	.6	--	--
NETWORK/MIDRANGE SYSTEMS Midrange systems, network servers and workstations	136.5	7.5	75.0	5.6
DESKTOP PERSONAL COMPUTERS Business and professional, single user	1,243.2	68.3	821.3	61.3
CONSUMER COMPUTERS Desktop PCs, game, and hobby computers	282.1	15.5	217.0	16.2
PORTABLE COMPUTERS Notebook and smaller mobile computers	29.1	1.6	32.2	2.4
OTHER APPLICATIONS	76.5	4.2	183.6	13.7
Total	1,820.2	100.0	1,339.8	100.0

TABLE 35

READ/WRITE OPTICAL DISK DRIVES, LESS THAN 4 GIGABYTES

MARKET SHARE SUMMARY
Worldwide Shipments of Noncaptive Disk Drives

	1998 Net Shipments							
	To United States Destinations				Worldwide			
	Units (000)			%	Units (000)			%
Drive Manufacturers	5.25"	3.5"	Total		5.25"	3.5"	Total	
Fujitsu	--	71.0	71.0	46.7	--	957.0	957.0	54.1
Olympus	--	26.0	26.0	17.1	--	520.0	520.0	29.4
Other U.S.	20.5	--	20.5	13.5	27.4	--	27.4	1.5
Other Non-U.S.	34.5	--	34.5	22.7	80.1	185.0	265.1	15.0
TOTAL	55.0	97.0	152.0	100.0	107.5	1662.0	1769.5	100.0

READ/WRITE OPTICAL DISK DRIVES, MORE THAN 4 GIGABYTES

READ/WRITE OPTICAL DISK DRIVES MORE THAN 4 GIGABYTES

Coverage

Examples of disk drives in this group include:

12" disk diameter

New ATG	GD 9001/SE, VFD 16000
Plasmon LMS	LD 6100

5.25" disk diameter

Maxoptix	To be announced (Rewritable)
TeraStor	To be announced (Rewritable)

All drives listed above are write-once unless otherwise indicated.

This product group includes optical disk drives with over 4 gigabytes of on-line capacity, reflecting increases in drive capacity level. High capacity optical disk drives are read/write drives, either write-once or rewritable. Currently, most drives in this capacity range are 12" write-once types, but a modest level of 1999 shipments of rewritable 5.25" drives is anticipated.

The 12" drives in this product group are used primarily with networked mini-computers and mainframes in imaging, document storage, or archiving applications. They are usually found in libraries that provide random access mass storage subsystems with hundreds of gigabytes of storage capacity. All of the currently manufactured drives in this group use 12" media. Plasmon LMS offers a drive that accesses both sides of the disk simultaneously. 12" optical libraries holding a single drive and fewer than 15 disks are also being used in departmental systems and small work groups. The anticipated 5.25" drives will be available with removable media, and will be used in libraries and large on-line storage arrays, and for video production and editing.

Market status

1998 unit shipments in this product group totaled 1,500 units (all 12" drives), a 37.5% decrease. The decline is a continuation of a multiyear slide in shipments of 12" drives, and with the departure of Eastman Kodak, leaves only Plasmon LMS and New ATG as surviving producers for coming years. Revenues for 1998 declined 29.4% to $25.0 million, due to lower shipments of 12" drives. 93.6% of worldwide revenues were generated in the U.S. market, though both producers are non-U.S. firms. 80.8% of revenues in 1998 were produced by sales to OEMs and integrators, while 19.2% were from distributor channels.

Government and financial organizations continue as major markets for high capacity disk drives in this group, and system integrators continue to quote on orders of significant magnitude, usually involving optical libraries plus drives. Higher capacity 5.25" MO drives may expand the market for this product group into general industry as they become available.

Marketing trends

Shipments of 12" drives are expected to increase slightly in 1999, as some users of 12" libraries stock up in anticipation of product end of life. Higher 12" drive capacities in the 20-30 gigabyte per disk range will also help extend user interest, but ultimately growth in 12" drives will succumb to the new 5.25" technologies. Initial shipments of 5.25" and smaller drives in this group have been substantially delayed, shifting the production ramp later in time, and Quinta, now a development arm of Seagate, has indicated they will not ship optical drives in the short term. However, 5.25" drive shipments are expected to begin in 1999 and rise sharply as the introduction of drives from Maxoptix, TeraStor, Sony and manufacturers building ASMO or other advanced drives returns a degree of vigor to the MO optical drive industry. U.S. firms are expected to be the earliest participants in the MO revival, with production from most Japanese drive producers following the initiation of U.S. produced drives.

New products anticipated are 4.55 gigabyte per side drives from Sony and others, 10 and 20 gigabyte near field recording drives from TeraStor, Maxoptix and others, and (less certainly) 6 gigabyte 4.72" MO ASMO drives. The 4.72" drive will probably read CD-ROM and DVD-ROM media, but not the existing 3.5" and 5.25" MO media. The potential availability and pricing of ASMO drives are currently too uncertain to include in forecasting. The competition from 5.25" drives is expected to limit the tendency of 12" drive prices to climb modestly each year, but delayed introduction of 5.25" drives in this group lessens the pressure on 12" drive prices. It is anticipated that all of the 5.25" drives in this product group will be rewritable or multifunction, but not all will necessarily use removable media. It is also expected that 3.5" drives will appear in this product group sometime toward the end of the forecast period, but that timetable is also not yet possible to forecast.

As a consequence of the arrival of small diameter drives in this product group, the average OEM unit price will fall sharply during the forecast period from over $15,000 to under $2,000. The 12" drive market will be severely stressed as a result, but shipments to companies already committed to 12" media in their libraries may keep the 12" market alive for a while. But of the nearly 680,000 drives in this product group expected to ship in 2002, only .6% will be 12" drives.

Sales revenues for 2002 are projected to reach nearly $625 million. Driven by usage in libraries and on-line storage arrays, U.S. markets are expected to retain the majority of worldwide revenues for this product group in the latter part of the forecast period. Most of the U.S. sales revenues will come from sales of 5.25" drives. 12" drive sales should be helped briefly by expanding sales of small optical libraries with a single 12" drive, plus a new generation of higher capacity drives, but ultimately will fall as drive makers cut prices to deal with the onslaught of small diameter drives.

Applications

Networks and multiuser systems remain the major application for drives in this group. The introduction of 5.25" drives in the group is expected to result in significant usage in video editing and production applications as well.

The majority of 12" drives were (and will be) installed in optical libraries. Libraries attached to mainframes used enough drives to account for 20.3% of group shipments in 1998. With the arrival of next generation 5.25" (or smaller) drives in this group, mainframe applications are expected to capture 15.4% of the 2002 total. Midrange systems, networks and workstations will capture 71.3% of 2002 shipments, with specialized high performance applications gaining an 11.2% share. The rest will be scattered among other platforms. If 3.5" drives materialize as anticipated, business personal computers might do better than the 2.7% share forecasted, and the .3% share of notebook computers might also be improved.

High capacity optical drives will probably have the performance and economics to make major inroads into the tape market. Not only are Maxoptix' and TeraStor's business plans predicated upon these characteristics, but with Quantum's investment in TeraStor and Seagate's acquisition of Quinta, a startup less than 2 years old at the time, there is ample evidence that the strategic planners at major disk drive producers also saw the potential.

Major applications for 12" optical disk drives include records management, medical, geophysical, military or industrial imaging, and storage of transaction documents required for future reference. Almost all of these applications are archival in nature and favor the use of write-once optical disk technology. As 5.25" and smaller drives increasingly participate in this product group, archival applications will become less dominant. Even so, many of the 5.25" drives may be used for archiving personal files, as will the newly proposed 4.72" MO drives if they actually materialize on schedule in 1999, as some potential suppliers have suggested. Data warehousing, imaging, video and audio editing, save/restore and data transfer are expected to become significant applications.

Scientific, industrial and defense oriented users of high capacity drives use them to store high volume digitized data from real time inputs as well as for administrative uses. Some financial institutions use them for accumulating various types of transaction data in other than image form, reproducing the actual form only upon printing or displaying the document. As 5.25" drives invade this product group, ruggedized versions are expected to appear in defense, aerospace and resource survey applications.

Early users of high capacity drives concentrated on the storage of images, including document filing systems used within government bodies such as taxing agencies, law enforcement, and military/intelligence agencies. Drive library units (jukeboxes) are available for use with high capacity optical disk drives, allowing the creation of on-line mass storage subsystems. These are being used by insurance companies, banks, and other large organizations that must have ready recall of large amounts of account related data needed to service account inquiries in real time. Many of the optical libraries are attached to file servers on networks, which are rapidly increasing their demands for on-line storage.

While the records management market is a significant consumer of high capacity optical disk drives, this market tends to experience slow growth due to its conservative nature. It exhibits reluctance to abandon large investments in existing systems (many of which are microfilm based), concern about hidden perils in new technology and, in some organizations, infighting between MIS managers and records managers. The legal systems of some countries discourage the use of optical disk storage systems, because only the original documents are acceptable as legal evidence. Where low cost is more important than rapid on-line retrieval of a record, microfilm still competes effectively against optical storage.

Large capacity optical disk drives will continue to be employed in dedicated departmental systems that store and manipulate engineering drawings, technical specifications and reference materials. These smaller systems will need smaller library units to meet departmental needs.

12" standalone drive applications in this product group have been impacted by lower capacity 5.25" diameter drives used with library units of 10-20 disk capacity and, in some cases, by large capacity magnetic rigid disk drives with capacities of 50 gigabytes or more. In these small systems, the total cost of the drives, library and media is often less than the price of a single 12" drive. The small diameter configurations then become preferable solutions where the longer access time associated with a library is not an objection, or it is acceptable to use a fixed rigid drive in combination with a removable drive that acts as a mailbox device. Furthermore, the advent of 1.3 gigabyte 5.25" based systems limited growth prospects for 12" systems, and the situation has been further aggravated by the arrival of each generation of higher capacity 5.25" drives.

Manufacturers of 12" drives are planning to offer increasingly higher capacities in order to keep their product lines viable, with capacity ultimately extending above 30 gigabytes per cartridge. It's a delaying action, at best.

Technical trends

Many of the technical issues discussed in the section on optical disk drives under 4 gigabytes capacity also apply to the larger capacity drives in this section. The issues are reviewed here as they pertain specifically to the higher capacity drives.

Performance: Almost all of the 12" products in this group currently use complex optical head assemblies, resulting in excessive head positioning times. This is of less consequence when the drive is used in a library subsystem, because of the time required to locate, mount, and spin-up the disk to operating speed. Plasmon LMS and New ATG have already broken the 100 millisecond barrier for 12" drives, and 5.25" drives in this group are expected to be largely sub-30 millisecond seek time devices. 5.25" drives will offer substantially higher rotation rates as a group than the 12" drives, and already have much shorter average access times. Data transfer rates in the 10 megabyte per second range are anticipated.

The current limit on rotational velocity for larger diameter disks is created by available laser write power and the performance of focus and tracking servos, rather than by material failure. 1,800 RPM is considered today's advanced state of the art for high capacity 12" drives. There are hopes of achieving higher RPM in the future through the use of nonmechanical focusing techniques and improved substrate materials. For smaller diameter drives, RPM can be higher, with most expected to rotate at 3,000 RPM or higher.

Standards: Because various manufacturer's 12" product designs are already established and incompatible, standardization for 12" drives has been limited. ECMA 190 and ISO 13403 apply to the 12" CCS format, while ECMA 189 and ISO 13614 apply to the 12" sampled servo format. ISO standard 10885 for 14" media (which affected only the Eastman Kodak drive) has also been completed. In any event, the continuous servo versus sampled servo conflict yet remains, and there is no standard for 12" rewritable media.

The 5.25" drives now entering this product group are expected to exhibit a far lower degree of standardization, since (with the exception of the Sony drive) the drives expected in 1999 and later represent completely new designs. While the 4.72" types are likely to be standardized by virtue of the work that has been accomplished by the sponsoring companies, it remains to be seen whether the other new technologies become well enough accepted to result in the undertaking of a standards effort. Of course, those that don't require removable media, such as the Quinta fixed media design, will not require much beyond compliance with standard logical interfaces such as SCSI, Ultra-SCSI and FC AL, and with industry form factor and packaging requirements. And if successful, the newcomers will probably create de facto standards prior to formal standards generation.

System design: Many large capacity optical disk storage systems incorporate an automated library. Several firms, including New ATG, Cygnet Storage Solutions, FileNet, Plasmon LMS, and others have designed libraries, discovering in the process that it is a major project, requiring substantial time and investment. To be a generally applicable product, the library may have to accommodate several brands of disk drives (though not all at once), an awkward consideration given the weak product standardization in the industry. The library unit also has to be interfaced to the computer system with which it is to be used, requiring significant development time. The drives themselves must be designed to withstand thousands of cartridge insertions without failure and must accommodate library control and signaling functions. By virtue of Hewlett-Packard's strong position in the optical library industry, its library interface definition has become a de facto standard.

Software: The software required to integrate a write-once optical disk into the operating system environment of a mainframe computer represents a major project, requiring many man-years of effort. The integration of erasable disks is easier, but even these present some problems. Aspects of the drive that are unique to optical storage can be masked by the controller, so that the optical storage subsystem appears as a standard magnetic disk to the operating system. Hierarchical storage management software will be required to make the best use of optical drives and libraries attached to network servers. Optical drives intended to replace tape drives or magnetic disk drives are expected to contain controllers that will enable direct replacement and not require extensive changes in system software.

Capacity: The family of 12" drives that started its introduction cycle in late 1994 offered over 16 gigabytes per disk, much improved from a typical capacity of 2 gigabytes per disk in earlier models, and is being extended to the 30 gigabyte range. More recent 12" drives now have dual heads, making the entire capacity of the cartridge available without the need to flip the disk.

As noted earlier, the anticipated 4.72" MO drives will offer 6 gigabytes of on-line capacity on a removable disk. The target capacities of the specific disk drives resulting from the TeraStor design program have been announced as 10 gigabytes, 20 gigabytes and 40 gigabytes per disk. Quinta's fixed disk drive capacity remains unannounced, but it is widely expected to be in the 100 gigabyte range, using multiple disks.

Interface: SCSI is the most commonly encountered interface family on large optical drives in this group. SCSI is likely to remain the preferred choice because of design commitments, or until drives with higher performance are technically possible. For drives to be sold to manufacturers of optical disk libraries, the use of the SCSI interface is a necessity. When they arrive, 4.72" drives in this group may find some requirement to support the ATAPI, USB and P1394 interfaces (assuming they do retain read compatibility with CD format drives), since they may be called upon to substitute for CD-ROM or DVD-ROM drives in some systems.

Lasers: Most drive producers are making the transition from infra-red lasers to red laser diodes in order to improve areal density. Blue-green, blue and violet lasers will be adopted as they become available, providing that they can meet price, output power, operating temperature and operating life requirements. Blue-green lasers may be in use toward the end of the forecast period, but it will probably take another few years to get blue or violet lasers acceptable for writable optical drive use into production.

Heads: Head design for advanced small optical drives is borrowing techniques from the magnetic drive design world, adopting rotary positioners and flying heads at microinch levels above the disk surface. In the case of near field recording, spacing must be minimized to get adequate energy coupling from the head to the media. Fly height control is critical in obtaining adequate and stable signal to noise ratios. In some designs, the laser is mounted off the slider itself, with energy routed through the use of optical fibers between laser and head. Linear positioning is used in 12" and in older 5.25" designs.

Media: Larger diameter media requires substrates that will not deform at high rotation rates and will maintain consistent optical properties over the usable area of the disk. The latter point is especially significant for magneto-optical media in which distortion caused by locked-in or dynamic stresses in the substrate creates signal degradation. These mechanical problems may be a significant obstacle to improving the performance of high capacity optical drives. The considerations for 5.25" media are much the same as in the low capacity drive group, although the drives using MO/rigid drive hybrid designs also require different media structures than conventional MO drives in order to minimize the path length between the head and the recording layer.

Some advanced designs will record and read on multiple layers, adding a vertical dimension to the tracking and servo requirements. In the case of Siros Technologies, this will be attempted with interferometric techniques, while others may use multiple fabricated media layers

Substrates: Both plastic and glass are in use for 12" media substrates, and Eastman Kodak is using an aluminum substrate for its 14" drive. Because of the difficulty in molding large diameter plastic substrates with adequately low birefringence, it seems likely that glass will retain a prominent role in the fabrication of readily producible erasable media for large diameter drives. 5.25" media for this product group has largely gone to plastic, while 4.72" media will use only plastic substrates. Surface irregularities and dimensional instabilities in plastic media create difficulties for drive designs requiring low flying heads, and it remains to be seen how acceptable plastic will be for these designs in actual practice.

Forecasting assumptions

1. 5.25" optical drives will become major participants in this product group in 1999. Only removable media types will be shipped. Both the Maxoptix and TeraStor programs are assumed to have successful, though delayed, outcomes. 4.72" ASMO drives will be introduced in late 1999 for 2000 delivery.

2. There will continue to be an adequate supply of media and components for drives in this product group.

3. There will be no generally accepted single standard for 12" drives and media through 2002. 30 gigabyte drives will be available in 1999.

4. 3.5" drives will appear in this product group during the forecast period, but the timing is too uncertain to permit forecasting.

TABLE 36

READ/WRITE OPTICAL DISK DRIVES, MORE THAN 4 GIGABYTES

REVENUE SUMMARY

	DISK DRIVE REVENUES, BY SHIPMENT DESTINATION ($M)									
	1998 Revenues		Forecast							
			1999		2000		2001		2002	
	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW
U.S. Manufacturers										
Distributor	--	--	--	--	14.0	19.6	31.2	57.6	62.0	110.0
OEM/Integrator	--	--	--	1.8	26.4	50.6	72.0	138.0	144.0	265.6
TOTAL U.S. NONCAPTIVE	--	--	--	1.8	40.4	70.2	103.2	195.6	206.0	375.6
TOTAL U.S. REVENUES	--	--	--	1.8	40.4	70.2	103.2	195.6	206.0	375.6
Non-U.S. Manufacturers										
Captive	--	--	--	--	1.2	3.0	3.8	10.1	4.8	13.2
Distributor	3.2	4.8	3.5	5.1	6.2	12.4	16.8	43.2	26.6	56.9
OEM/Integrator	20.2	20.2	22.0	23.7	33.1	54.1	68.7	138.5	86.4	179.2
TOTAL NON-U.S. REVENUES	23.4	25.0	25.5	28.8	40.5	69.5	89.3	191.8	117.8	249.3
Worldwide Recap										
TOTAL WORLDWIDE REVENUES	23.4	25.0	25.5	30.6	80.9	139.7	192.5	387.4	323.8	624.9
OEM Average Price ($000)		15.538		9.807		2.792		2.133		1.693

TABLE 37

READ/WRITE OPTICAL DISK DRIVES, MORE THAN 4 GIGABYTES

UNIT SHIPMENT SUMMARY

	DISK DRIVE UNIT SHIPMENTS, BY SHIPMENT DESTINATION (000)									
	1998 Shipments		Forecast							
			1999		2000		2001		2002	
	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW
U.S. Manufacturers										
Distributor	--	--	--	--	5.0	7.0	13.0	24.0	31.0	55.0
OEM/Integrator	--	--	--	1.2	12.0	23.0	36.0	69.0	90.0	166.0
TOTAL U.S. NONCAPTIVE	--	--	--	1.2	17.0	30.0	49.0	93.0	121.0	221.0
TOTAL U.S. SHIPMENTS	--	--	--	1.2	17.0	30.0	49.0	93.0	121.0	221.0
Non-U.S. Manufacturers										
Captive	--	--	--	--	.4	1.0	1.5	4.0	2.2	6.0
Distributor	.1	.2	.1	.2	1.6	3.2	6.1	16.2	11.2	25.3
OEM/Integrator	1.3	1.3	1.3	1.4	6.3	14.5	25.4	60.6	41.4	96.7
TOTAL NON-U.S. SHIPMENTS	1.4	1.5	1.4	1.6	8.3	18.7	33.0	80.8	54.8	128.0
Worldwide Recap										
TOTAL WORLDWIDE SHIPMENTS	1.4	1.5	1.4	2.8	25.3	48.7	82.0	173.8	175.8	349.0
Cumulative Shipments (Units in thousands)										
WORLDWIDE TOTAL	54.4	105.6	55.8	108.4	81.1	157.1	163.1	330.9	338.9	679.9

TABLE 38

READ/WRITE OPTICAL DISK DRIVES, MORE THAN 4 GIGABYTES

WORLDWIDE REVENUES ($M)

BREAKDOWN BY DISK DIAMETER

	1998 Revenues	Forecast							
		1999		2000		2001		2002	
	12"-14"	12"-14"	5.25"	12"-14"	5.25"	12"-14"	5.25"	12"-14"	5.25"
U.S. MANUFACTURERS									
Distributor	--	--	--	--	19.6	--	57.6	--	110.0
OEM/Integrator	--	--	1.8	--	50.6	--	138.0	--	265.6
TOTAL U.S. REVENUES	--	--	1.8	--	70.2	--	195.6	--	375.6
NON-U.S. MANUFACTURERS									
Captive	--	--	--	--	3.0	--	10.1	--	13.2
Distributor	4.8	5.1	--	4.8	7.6	4.8	38.4	6.9	50.0
OEM/Integrator	20.2	23.7	--	25.5	28.6	26.4	112.1	27.2	152.0
TOTAL NON-U.S. REVENUES	25.0	28.8	--	30.3	39.2	31.2	160.6	34.1	215.2
WORLDWIDE RECAP									
Captive	--	--	--	--	3.0	--	10.1	--	13.2
	--	--	--	--	--	--	+236.7%	--	+30.7%
Distributor	4.8	5.1	--	4.8	27.2	4.8	96.0	6.9	160.0
	-41.5%	+6.3%	--	-5.9%	--	--	+252.9%	+43.8%	+66.7%
OEM/Integrator	20.2	23.7	1.8	25.5	79.2	26.4	250.1	27.2	417.6
	-16.5%	+17.3%	--	+7.6%	--	+3.5%	+215.8%	+3.0%	+67.0%
Total Revenues	25.0	28.8	1.8	30.3	109.4	31.2	356.2	34.1	590.8
	-29.4%	+15.2%	--	+5.2%	--	+3.0%	+225.6%	+9.3%	+65.9%
ANNUAL SHARE, BY DIAMETER	100.0%	94.2%	5.8%	21.7%	78.3%	8.1%	91.9%	5.5%	94.5%

Note: 5.25 inch drive totals include 4.72 inch drives.

TABLE 39

READ/WRITE OPTICAL DISK DRIVES, MORE THAN 4 GIGABYTES

WORLDWIDE SHIPMENTS (000)

BREAKDOWN BY DISK DIAMETER

	1998 Shipments	Forecast							
		1999		2000		2001		2002	
	12"-14"	12"-14"	5.25"	12"-14"	5.25"	12"-14"	5.25"	12"-14"	5.25"
U.S. MANUFACTURERS									
Distributor	--	--	--	--	7.0	--	24.0	--	55.0
OEM/Integrator	--	--	1.2	--	23.0	--	69.0	--	166.0
TOTAL U.S. SHIPMENTS	--	--	1.2	--	30.0	--	93.0	--	221.0
NON-U.S. MANUFACTURERS									
Captive	--	--	--	--	1.0	--	4.0	--	6.0
Distributor	.2	.2	--	.2	3.0	.2	16.0	.3	25.0
OEM/Integrator	1.3	1.4	--	1.5	13.0	1.6	59.0	1.7	95.0
TOTAL NON-U.S. SHIPMENTS	1.5	1.6	--	1.7	17.0	1.8	79.0	2.0	126.0
WORLDWIDE RECAP									
Captive	--	--	--	--	1.0	--	4.0	--	6.0
	--	--	--	--	--	--	+300.0%	--	+50.0%
Distributor	.2	.2	--	.2	10.0	.2	40.0	.3	80.0
	-60.0%	--	--	--	--	--	+300.0%	+50.0%	+100.0%
OEM/Integrator	1.3	1.4	1.2	1.5	36.0	1.6	128.0	1.7	261.0
	-27.8%	+7.7%	--	+7.1%	--	+6.7%	+255.6%	+6.3%	+103.9%
Total Shipments	1.5	1.6	1.2	1.7	47.0	1.8	172.0	2.0	347.0
	-37.5%	+6.7%	--	+6.3%	--	+5.9%	+266.0%	+11.1%	+101.7%
ANNUAL SHARE, BY DIAMETER	100.0%	57.2%	42.8%	3.5%	96.5%	1.0%	99.0%	.6%	99.4%

Note: 5.25 inch drive totals include 4.72 inch drives.

TABLE 40

READ/WRITE OPTICAL DISK DRIVES, MORE THAN 4 GIGABYTES

APPLICATIONS SUMMARY
Percentage of Worldwide Shipments

APPLICATION	1998 Estimate Units (000)	1998 Estimate %	2002 Projection Units (000)	2002 Projection %
SPECIALIZED HIGH PERFORMANCE Supercomputers, video and high end imaging	--	--	39.1	11.2
MAINFRAME SYSTEMS General purpose	.3	20.3	15.4	4.4
NETWORK/MIDRANGE SYSTEMS Midrange systems, network servers and workstations	.8	55.6	248.8	71.3
DESKTOP PERSONAL COMPUTERS Business and professional, single user	.1	4.3	9.4	2.7
CONSUMER COMPUTERS Desktop PCs, game, and hobby computers	--	--	.7	.2
PORTABLE COMPUTERS Notebook and smaller mobile computers	--	--	1.0	.3
OTHER APPLICATIONS	.3	19.8	34.6	9.9
Total	1.5	100.0	349.0	100.0

TABLE 41

READ/WRITE OPTICAL DISK DRIVES, MORE THAN 4 GIGABYTES

MARKET SHARE SUMMARY
Worldwide Shipments of Noncaptive Disk Drives

	1998 Net Shipments							
	To United States Destinations				Worldwide			
	Units (000)			%	Units (000)			%
Drive Manufacturers	12-14"	5.25"	Total		12-14"	5.25"	Total	
Plasmon LMS	1.3	--	1.3	92.9	1.3	--	1.3	86.7
Other U.S.	--	--	--	--	--	--	--	--
Other Non-U.S.	.1	--	.1	7.1	.2	--	.2	13.3
TOTAL	1.4	--	1.4	100.0	1.5	--	1.5	100.0

RIGID DISK CARTRIDGE DRIVES

RIGID DISK CARTRIDGE DRIVES

Coverage

Examples of disk drives in this group include:

3.5" disk diameter

Castlewood Systems	ORB2
Iomega	Jaz 1, Jaz 2

The range of disk drives available in this product group, which includes all types of disk drives using removable media in the form of rigid disk cartridges, has seen major changes in the last year. Until 1995, 5.25" disk drives provided the majority of shipments in the disk cartridge drive product group. However, SyQuest's 3.5" drives became available in 1992, and total shipments of 3.5" drives passed up the 5.25" form factor in 1995.

In response to the Iomega initial market success with the Zip 100 megabyte high capacity 3.5" floppy drive, SyQuest introduced in 1995 the "EZ" single head 3.5" disk cartridge drive designed for very low cost, with capacity initially at 135 megabytes, followed by the 230 megabyte EZFlyer in mid-1996. The capacity range of disk cartridge drives was significantly increased in December, 1995, with the Iomega introduction of the 1 gigabyte Jaz 3.5" drive, using a two disk cartridge. In response, SyQuest offered the SyJet, a 3.5" drive with a capacity of 1.5 gigabytes using a two disk cartridge, with deliveries starting in December, 1996, followed in the first quarter of 1998 by Iomega's Jaz 2, with 2 gigabytes.

Competitors in the rigid disk cartridge field have struggled to find the optimum product type for the market. Iomega's products introduced to date have used two 3.5" disks in each cartridge, in an attempt to offer the highest available capacities, despite the additional cost of using a second disk. SyQuest attempted to capture market share with the 3.5" SparQ 1 gigabyte single disk cartridge drive, designed for low manufacturing cost. Castlewood Systems has also used a single 3.5" disk in the 2 gigabyte ORB2, with shipments initiated in the first quarter of 1999. The Avatar 2.5" disk cartridge drives, in a series of models with various capacities up to 250 megabytes, were first shipped in 1993, with volume production at the company's Thailand plant. Demand for the Avatar 2.5" drives never reached the expected levels, and Avatar ceased operations in 1998.

Market status

1998 was a year of significant changes in the rigid disk cartridge drive business. By the end of the year, the most aggressive advertising and sales promotion campaigns in the history of disk cartridge drives had been undertaken, all manufacturers produced sales at disappointing levels, and three companies were no longer making drives. 1998 worldwide unit shipments were down 10.3% from the previous year, at 1,289,700 drives, and the DISK/TREND forecast for 1999 shipments is down another 24.7%, at 970,000 units. 1998 sales revenues for the product group were $271.1 million, a decline of 21.7%, with 1999 projected at $180.6, a drop of 33.4%.

The product group's major casualty in 1998 was SyQuest, which stopped operations in early November, followed by Chapter 11 bankruptcy. SyQuest's turnaround management initiated production of the company's 1 gigabyte SparQ in late 1997, and emphasized increasing production, intense market development programs and aggressive pricing during 1998. The firm shipped 530.7 thousand drives during 1998, but sales at that level, combined with low prices and high sales and promotion expenses, proved to be a losing business. During the bankruptcy proceedings, Iomega arranged to purchase all of SyQuest's intellectual property, U.S. fixed assets and inventory for $9.1 million. The remaining service and warranty business, and some limited sales activity, is continuing under the name SYQT, Inc. It is expected that Iomega will probably license a company specializing in disk drive service and limited production programs to manufacture current SyQuest drive models to satisfy existing demand.

Since its founding in 1991, Avatar had gradually increased the capacity of its 2.5" disk cartridge drive from the initial 85 megabytes to 250 megabytes, while searching for a market of significant size. After shipping almost 200,000 drives in 1997, Avatar's attempt to develop a distribution market had apparently peaked, with declining sales in 1998. The company ceased operations at midyear. The French firm Nomai S.A. also left the disk drive manufacturing field during 1998. Nomai entered the disk cartridge drive field in late 1995, after making disk cartridge media products for several years, with drive production in the U.K. on a contract basis by Xyratex. Nomai attracted lawsuits in several countries by

Iomega by offering a Zip compatible floppy disk cartridge, a problem which Iomega solved by buying control of Nomai in mid-1998 for $42 million. One of the results of that purchase was the withdrawal of Nomai's rigid disk cartridge drives from the market.

Although SyQuest's initial growth in disk cartridge drive shipments was built on the company's original 3.9" drives, the 44 megabyte 5.25" model introduced in 1987 became the dominant "prepress" interchange standard for graphics, typography and other original material used in printing, as projects move from designers, art departments and advertising agencies to typographers and printers. But despite capacity upgrades eventually reaching 200 megabytes in 1994, the market growth for 5.25" rigid disk cartridge drives slowed down, as customers' appetites for even higher capacities became stronger. 5.25" drive shipments started declining in 1995, and in 1998 were only 3,100 drives.

For years the most aggressive competition for SyQuest's pioneering rigid disk cartridge drives was provided by the Iomega 5.25" high capacity Bernoulli floppy disk drive. Iomega's Bernoulli drives increased in capacity over the years, up to 230 megabytes, with the result that SyQuest and Iomega competed directly in both the Macintosh and IBM personal computer markets for the same graphics and desktop publishing applications. Until 1995, SyQuest's disk cartridge drives held a clear lead in these markets, due to a successful strategy of concentrating on the Macintosh market, the leader in desktop publishing. SyQuest's EZ drive series, initially with 135 and later with 230 megabytes, was intended for many of the same markets as Iomega's successful Zip high capacity floppy drive. SyQuest's disastrous financial results during recent years illustrate the difficulty in competing against a high capacity floppy drive optimized for low production cost with a rigid disk equivalent. With the advent of the 1 gigabyte 3.5" Jaz drive at the end of 1995, followed by additional drives in the 1-2 gigabyte range from both SyQuest and Iomega, rigid disk cartridge drives were able to address a broader range of applications, resulting in increased sales levels through 1997.

Several types of disk drives compete in the same markets addressed by rigid disk cartridge drives. It must be noted that the majority of personal computer users are satisfied with the generous capacities now available on the fixed disk drives which are standard equipment on their PCs. For PC owners with a functional or perceived need for a removable media drive, they have a choice of magnetic disk cartridge drives, high capacity floppy drives and various types of rewritable optical disk drives.

Although it is clear that the market for the remaining 3.5" disk cartridge drives is softer in 1999 than in the last few years, it is not clear which of the apparent reasons are contributing the greatest impact. It is possible that 1998's intense sales promotion by SyQuest and Iomega confused as many potential buyers as it convinced, as they tried to decide which to buy. Rapid growth of the market for CD-RW rewritable optical drives may have diverted potential customers to that format. And, of course, it may merely be the case that the current market for rigid disk cartridge drives is a limited business and professional market which has become saturated.

Iomega was again the leader in worldwide unit shipments in 1998, with 712,000 drives for 55.2% of the overall total, but that figure was below the company's 818,000 Jaz drive total in 1997. SyQuest's 530,700 drives, all 3.5" except for 3,100 5.25" models, were 41.2% of the industry total. In 1998, all disk cartridge drives were shipped in noncaptive market channels, predominantly in the Distributor channel.

Marketing trends

Despite the softer 1999 market for rigid disk cartridge drives, a pattern of increasing shipments is expected in future years, but with somewhat lower expectations than in previous years. The current DISK/TREND forecast indicates an average annual increase in the 2000-2002 period of 23.4%, with unit shipments of 1.8 million drives in 2002. Sales revenues are expected to achieve a more modest average annual increase of 10.4%, yielding 2002 revenues of $242.5 million, limited by falling average unit prices.

With SyQuest no longer in the game, the only current competitor to Iomega's Jaz product line is Castlewood Systems, founded in 1996 by Syed Iftikar, an industry veteran who originally founded SyQuest. Castlewood is using contract manufacturers in Southeast Asia to manufacture its drive, a single disk design with potentially lower cost than the two platter Iomega Jaz series. Iomega is expected to introduce a single disk 3.5" cartridge drive, but the timetable is uncertain. If Castlewood is able to obtain significant quantities of drives, with appropriate cost and quality, the firm clearly can gain a sizable share of the market. It has been demonstrated that the market for disk cartridge drives in the over 1 gigabyte range is greater than a million drives per year. The eventual market size will depend upon how many potential users doing sophisticated projects will find this recording medium to be convenient and cost effective -- and whether the drive manufacturers provide solutions they can live with.

Technical trends

The basic recording technologies now in use for products in this group will continue to predominate for years. The disk drives now in quantity production embody the mechanical design lessons accumulated during years of production of larger removable disk drives, and will be able to exploit the rapid advances in recording technology from other segments of the disk drive industry. Disk cartridge drives may be expected to increase continually in capacity during the coming years, following closely the rapid improvements in areal density expected with fixed disk drives.

Iomega's Jaz drive family provides an illustration of the benefits which accrue to this product group from the much higher production levels now achieved with fixed disk drives manufactured for the desktop personal computer market. Each Jaz 2 cartridge uses two 1 gigabyte disks, the type used in the highest volume fixed disk drives in 1996. Castlewood's drive uses a single 2 gigabyte disk, the type which peaked in shipments in 1998. As recording capacities increase at the expected 60% per year, disks, heads and semiconductors manufactured for the industry's highest volume fixed disk drives will become available to the manufacturers of disk cartridge drives at low costs. With these components available, it is to be expected that capacities available in 3.5" disk cartridge drives will track the same upward trend, probably following fixed disk drives by a year or two.

Forecasting assumptions

1. Shipments of 3.5" disk cartridge drives will increase, primarily due to demand in specialized business and professional markets, with further increases in drive capacity available, and with sales predominantly in the aftermarket.

2. There will be no further production of 2.5" or 5.25" disk cartridge drives.

TABLE 42

RIGID DISK CARTRIDGE DRIVES

REVENUE SUMMARY

	DISK DRIVE REVENUES, BY SHIPMENT DESTINATION ($M)									
	1998 Revenues		Forecast							
			1999		2000		2001		2002	
	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW
U.S. Manufacturers										
Distributor	189.3	239.5	107.8	157.1	96.3	160.2	114.0	175.4	129.4	199.4
OEM/Integrator	17.9	27.1	13.8	23.5	15.2	27.7	20.3	35.1	25.7	43.1
TOTAL U.S. REVENUES	207.2	266.6	121.6	180.6	111.5	187.9	134.3	210.5	155.1	242.5
Non-U.S. Manufacturers										
Distributor	.9	4.5	--	--	--	--	--	--	--	--
TOTAL NON-U.S. REVENUES	.9	4.5	--	--	--	--	--	--	--	--
Worldwide Recap										
TOTAL WORLDWIDE REVENUES	208.1	271.1	121.6	180.6	111.5	187.9	134.3	210.5	155.1	242.5
OEM Average Price ($000)		.238		.195		.178		.156		.139

TABLE 43

RIGID DISK CARTRIDGE DRIVES

UNIT SHIPMENT SUMMARY

	DISK DRIVE UNIT SHIPMENTS, BY SHIPMENT DESTINATION (000)									
	1998 Shipments		Forecast							
			1999		2000		2001		2002	
	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW
U.S. Manufacturers										
Distributor	921.8	1,151.2	555.0	850.0	580.0	965.0	770.0	1,185.0	980.0	1,510.0
OEM/Integrator	75.3	113.5	65.0	120.0	85.0	155.0	130.0	225.0	185.0	310.0
TOTAL U.S. SHIPMENTS	997.1	1,264.7	620.0	970.0	665.0	1,120.0	900.0	1,410.0	1,165.0	1,820.0
Non-U.S. Manufacturers										
Distributor	5.0	25.0	--	--	--	--	--	--	--	--
TOTAL NON-U.S. SHIPMENTS	5.0	25.0	--	--	--	--	--	--	--	--
Worldwide Recap										
TOTAL WORLDWIDE SHIPMENTS	1,002.1	1,289.7	620.0	970.0	665.0	1,120.0	900.0	1,410.0	1,165.0	1,820.0
Total Capacity (Terabytes)	1,290.7	1,669.8	1,128.0	1,802.0	1,197.0	2,016.0	1,800.0	2,820.0	2,912.5	4,550.0
Cumulative Shipments (Units in millions)										
WORLDWIDE TOTAL	5.3	7.9	6.0	8.8	6.6	10.0	7.5	11.4	8.7	13.2

TABLE 44

RIGID DISK CARTRIDGE DRIVES

WORLDWIDE REVENUES ($M)

BREAKDOWN BY DISK DIAMETER

	1998 Revenues			Forecast			
	5.25"	3.5"	2.5"	1999 3.5"	2000 3.5"	2001 3.5"	2002 3.5"
U.S. MANUFACTURERS							
Distributor	.6	235.6	3.3	157.1	160.2	175.4	199.4
OEM/Integrator	.3	26.8	--	23.5	27.7	35.1	43.1
TOTAL U.S. REVENUES	.9	262.4	3.3	180.6	187.9	210.5	242.5
NON-U.S. MANUFACTURERS							
Distributor	--	4.5	--	--	--	--	--
TOTAL NON-U.S. REVENUES	--	4.5	--	--	--	--	--
WORLDWIDE RECAP							
Distributor	.6	240.1	3.3	157.1	160.2	175.4	199.4
	-95.8%	-3.9%	-91.6%	-34.6%	+2.0%	+9.5%	+13.7%
OEM/Integrator	.3	26.8	--	23.5	27.7	35.1	43.1
	-93.9%	-26.2%	--	-12.3%	+17.9%	+26.7%	+22.8%
Total Revenues	.9	266.9	3.3	180.6	187.9	210.5	242.5
	-95.3%	-6.7%	-91.9%	-32.3%	+4.0%	+12.0%	+15.2%
ANNUAL SHARE, BY DIAMETER	.3%	98.6%	1.1%	100.0%	100.0%	100.0%	100.0%

TABLE 45

RIGID DISK CARTRIDGE DRIVES

WORLDWIDE SHIPMENTS (000)

BREAKDOWN BY DISK DIAMETER

	1998 Shipments 5.25"	1998 Shipments 3.5"	1998 Shipments 2.5"	Forecast 1999 3.5"	Forecast 2000 3.5"	Forecast 2001 3.5"	Forecast 2002 3.5"
U.S. MANUFACTURERS							
Distributor	2.1	1,127.1	22.0	850.0	965.0	1,185.0	1,510.0
OEM/Integrator	1.0	112.5	--	120.0	155.0	225.0	310.0
TOTAL U.S. SHIPMENTS	3.1	1,239.6	22.0	970.0	1,120.0	1,410.0	1,820.0
NON-U.S. MANUFACTURERS							
Distributor	--	25.0	--	--	--	--	--
TOTAL NON-U.S. SHIPMENTS	--	25.0	--	--	--	--	--
WORLDWIDE RECAP							
Distributor	2.1	1,152.1	22.0	850.0	965.0	1,185.0	1,510.0
	-94.6%	+11.5%	-88.6%	-26.2%	+13.5%	+22.8%	+27.4%
OEM/Integrator	1.0	112.5	--	120.0	155.0	225.0	310.0
	-94.0%	-25.5%	--	+6.7%	+29.2%	+45.2%	+37.8%
Total Shipments	3.1	1,264.6	22.0	970.0	1,120.0	1,410.0	1,820.0
	-94.4%	+6.8%	-89.0%	-23.3%	+15.5%	+25.9%	+29.1%
ANNUAL SHARE, BY DIAMETER	.2%	98.2%	1.6%	100.0%	100.0%	100.0%	100.0%
TOTAL CAPACITY (Terabytes)	.9	1,663.4	5.5	1,802.0	2,016.0	2,820.0	4,550.0

TABLE 46

RIGID DISK CARTRIDGE DRIVES

WORLDWIDE PRICE PER MEGABYTE ($/MB)

DISK DIAMETER	1998	Forecast 1999	2000	2001	2002
Distributor					
5.25"	.875	--	--	--	--
3.5"	.160	.100	.092	.074	.053
2.5"	.600	--	--	--	--
Distributor Average	.162	.100	.092	.074	.053
OEM/Integrator					
5.25"	.833	--	--	--	--
3.5"	.161	.102	.099	.078	.056
2.5"	--	--	--	--	--
OEM/Integrator Average	.162	.102	.099	.078	.056

Note: Price per megabyte calculations represent estimated total sales revenues for each product type divided by the total yearly shipped capacity of all drives of that type.

TABLE 47

RIGID DISK CARTRIDGE DRIVES

APPLICATIONS SUMMARY
Percentage of Worldwide Shipments

APPLICATION	1998 Estimate Units (000)	1998 Estimate %	2002 Projection Units (000)	2002 Projection %
SPECIALIZED HIGH PERFORMANCE				
Supercomputers, video and high end imaging	24.4	1.9	41.9	2.3
MAINFRAME SYSTEMS				
General purpose	--	--	--	--
NETWORK/MIDRANGE SYSTEMS				
Midrange systems, network servers and workstations	206.4	16.0	96.5	5.3
DESKTOP PERSONAL COMPUTERS				
Business and professional, single user	892.5	69.2	1,577.9	86.7
CONSUMER COMPUTERS				
Desktop PCs, game, and hobby computers	109.6	8.5	69.2	3.8
PORTABLE COMPUTERS				
Notebook and smaller mobile computers	29.7	2.3	21.8	1.2
OTHER APPLICATIONS	27.1	2.1	12.7	.7
Total	1,289.7	100.0	1,820.0	100.0

TABLE 48

RIGID DISK CARTRIDGE DRIVES

MARKET SHARE SUMMARY
Worldwide Shipments of Noncaptive Disk Drives

	1998 Net Shipments									
	To United States Destinations					Worldwide				
	Units (000)				%	Units (000)				%
Drive Manufacturers	5.25"	3.5"	2.5"	Total		5.25"	3.5"	2.5"	Total	
Iomega	--	525.0	--	525.0	52.4	--	712.0	--	712.0	55.2
SyQuest	2.6	449.5	--	452.1	45.1	3.1	527.6	--	530.7	41.2
Other U.S.	--	--	20.0	20.0	2.0	--	--	22.0	22.0	1.7
Other Non-U.S.	--	5.0	--	5.0	.5	--	25.0	--	25.0	1.9
TOTAL	2.6	979.5	20.0	1002.1	100.0	3.1	1264.6	22.0	1289.7	100.0

CARD FORMAT RIGID DISK DRIVES

CARD FORMAT RIGID DISK DRIVES

Coverage

Examples of disk drives in this group include:

PC Card Type III (10.5 mm height)	
Calluna Technology	CT-1040RM, CT-521RM
PCS, Inc.	Integral 8170E, 8340PA
PC Card Type II (5 mm height)	
Calluna Technology	CT-260T2
CompactFlash Card Type II (5 mm height)	
IBM	Microdrive 170, 340
CompactFlash Card Type I (3.3 mm height)	
Halo Data Devices	Halo Ultra

All of the 1.8" rigid disk drives currently included in this section conform to the PCMCIA PC Card specifications, which define allowable card dimensions and connectors. Calluna Technology continues to manufacture 1.8" rigid disk drives, the lone survivor from among ten manufacturers which announced such drives during the 1990's. Each of Calluna's 1.8" drives now in production adhere to the PC Card Type III specification, with a height of 10.5 millimeters, but production of a Calluna 260 megabyte Type II drive, 5 millimeters high, is expected to start soon, utilizing a contract manufacturing arrangement in Singapore with PCS, Inc.

Several disk drive manufacturers introduced 1.8" drives in the PC Card format, starting with Integral Peripheral's 20 megabyte model, first produced in 1991. In the early 1990's, 1.8" drives appeared to have a significant market potential, but the PC Card format was too large to be conveniently used with most handheld mobile devices and 1.8" drives couldn't compete against the price per megabyte available with the 2.5" drives used in notebook computers. Most of the announced 1.8" drive manufacturers gradually dropped out, and Integral Peripheral's 1.8" program was finally phased out in early 1998. Currently, the only manufacturers of 1.8" drives are Calluna Technology and PCS, which produces limited quantities of some Integral Peripheral models. Calluna has increased the capacity of its 10.5 millimeter thick PC Card Type III drives to 1 gigabyte.

The potential role in computer and consumer electronics applications of card format drives with 1" disk diameters is open to speculation. IBM has started production in mid-1999 of its "Microdrive", in the CompactFlash Type II format, with 5 millimeter height. It has a capacity of 340 megabytes in the version using two heads, or 170 megabytes using one head. IBM's published development roadmaps indicate an expected capacity for the format of over 1 gigabyte within a few years. Halo Data Devices is planning to produce, on an unannounced timetable, a 265 megabyte drive in the CompactFlash standard 3.3 millimeter Type I format, using a single head.

For the first time, drives using 1" disks will make it possible to greatly increase the features offered with handheld computers, mobile GPS systems, digital cameras and other mobile devices. For example, it will be possible to add voice recognition capability to handheld computers, which could offer complete word processing systems and other features. Following IBM's start of microdrive shipments in June, 1999, and assuming that the promised capacity increases during the next few years actually materialize, the time required to develop the new mobile devices which will utilize the new card format 1" disk drives is the pacing element which will control development of the market.

Market status

1.8" PC Card drives were the only type of disk drive for which there were any 1998 sales in this product group. PC Card drives have declined in shipments during each of the last three years. The shipment total for 1998 was 115,900 drives, producing sales revenues of $36.4 million. Despite the decline during recent years, 1999 unit shipments are forecasted to increase to 153,000 drives, boosted by availability of higher PC Card drive capacities, production of new PC Card Type II drives, and initial shipments of 1" CompactFlash Card drives.

In the early 1990's, many participants in the disk drive industry had high expectations for this product group -- with the result that the overall amount of money spent for product development, production facilities and market development for disk drives in removable card formats was probably several times greater than the total sales revenues achieved to date. After anticipating that the market for PC Card drives would expand beyond the initial specialized applications, drive manufacturers were confronted with minimal usage with "personal digital assistants", subnotebook computers and notebook computers, and continued delays in development of targeted potential new applications.

At the beginning of 1998, only two manufacturers, Calluna Technology and Integral Peripherals, were active participants in the product area, with shipments limited by the small size of existing markets and slower than expected development cycles for some of the newer applications for PC Card drives. Integral's lack of momentum resulted in bankruptcy in the first half of 1998, leaving the field to Calluna. The new development in mid-1999 has been the start of IBM's shipments of the company's unique 1" Microdrive, a product with significant potential sales in several mobile applications, but with modest shipments expected in 1999.

Shipments of PC Card drives with notebook computers have been much smaller than several drive manufacturers expected, due to the slow rate of progress computer manufacturers have experienced in reducing the size and weight of notebook computers, combined with the fact that PC Card drives have tended to offer capacities which have not kept up with the levels demanded for new notebook computers. 2.5" drives are used with substantially all of the notebook computers made today, chosen by system manufacturers because available 2.5" drive capacities are higher, and prices are lower, than the capacities and prices available with 1.8" PC Card drives. There is also a less aggressive pattern of reduction in size and weight for notebook computers than was previously expected, minimizing one of the key potential reasons for system manufacturers to move to PC Card disk drives.

Drive manufacturers were in a race in the early 1990's to increase drive capacities of 1.8" drives as rapidly as possible. As long as the possibility of substantial markets for 1.8" drives with notebook computers seemed imminent, manufacturers of PC Card drives moved capacities upward as rapidly as possible, reaching 340 megabytes native drive capacity by the end of 1994. 1 gigabyte PC Card drives are currently available, but there now appears to be less pressure to quickly move beyond this capacity level. As the lone PC Card drive manufacturer, Calluna is expected to continue its strategy of minimizing sales activities for the low end of the capacity ranges currently available, and will emphasize development of markets for its higher capacity drives.

Marketing trends

The actual growth rate to be achieved through 2002 by 1.8" and smaller drives will depend on how rapidly new applications are developed to take advantage of the storage capacity made available by these drives. Cost effective storage devices offering hundreds of megabytes of capacity have never before been available in form factors as small as the CompactFlash card. Software developers and system designers will be able to explore completely new applications, but a prudent forecast must assume that actual shipment demand for the new drives during the first few years of availability will be modest.

Overall unit shipments for card format rigid disk drives are forecasted to increase at an average annual rate of 64.1% in the 2000-2002 period, with shipments for the product group reaching 750,000 units in 2002. The average annual increase in sales revenues during the same period is projected at 28.3%, reaching $96.7 million, reflecting changes in product mix and a trend to lower average unit prices. In 2002, 63.3% of the product group's total shipments are projected to be 1" card format drives, with an average price per megabyte of 7 cents.

Based on the continuing demand for PC Card drives in several specialized markets and the apparent financial stability of the sole remaining manufacturer, a modest rate of annual increases is expected through the remainder of the current forecast period. Potential additional applications for these drives still exist and growth is expected, even though the timetable has many uncertainties.

Type II PC Card drives are expected to utilize only a single 1.8" disk because of size constraints, and the capacity available will be limited. However, the disk drive industry's areal densities are increasing very rapidly, and within a few years, it will be possible to produce Type II PC Card drives with capacities well beyond the 260 megabytes of the announced Calluna Type II drive. It is possible that availability of Type II drives could keep overall drive shipments in the lower capacity ranges at a higher level than otherwise would be expected, due to a wider market and lower prices than available for Type III drives.

To some extent, the energy level expended in developing new applications for 1" drives will depend upon the computer industry's perception of how serious IBM is in developing manufacturing capability and in further enhancements to the drive series, including increased capacity. If IBM follows through on the initial strong market introduction, it is expected that application development will follow. In addition, the single remaining drive manufacturer active in the 1.8" product area, and any others which choose to participate, could move above the 1 gigabyte level within the next few years, taking advantage of head, disk and semiconductor technology already developed for larger diameter drives.

Technical trends

Most of the industry's landmark new rigid disk drives are now typically designed for capacity levels much higher than those of this product group. During the last few years, developing disk drives for the low capacity ranges became a sophisticated exercise in applied engineering, in which nothing new had to be invented, but many leading edge components had to be available in large quantities, assembled with great precision, and delivered in a reliable, low-cost mechanism. During the rest of this forecast period it is expected that the rigid disk drive industry will continue to increase areal density by at least 60% per year. Critical to this rate of increase is the ability to create smoother disks, recording heads which can utilize narrower tracks, more magnetic flux reversals per linear inch, and development of semiconductors which can process much faster data transfer rates.

The technical challenges for the miniaturized disk drives to be developed in this capacity range during the next few years will have to exploit the low cost production techniques utilized for the earlier drive designs, compressed into an amazingly small form factor. Designers will be challenged to combine extreme reduction in parts count, mechanical engineering akin to a watchmaker's, new techniques for automated assembly, the latest technology in areal density, and extremely low cost targets. Some of the industry's most interesting products could result from these efforts.

Forecasting assumptions

1. 1.8" PC Card drive shipments will continue through 2002, with a base of specialized applications and limited usage with notebook computers.
2. Significant production capacity for CompactFlash Card 1" drives will be established in 1999, with increasing drive capacities through 2002, and gradual development of applications through 2002.

TABLE 49

CARD FORMAT RIGID DISK DRIVES

REVENUE SUMMARY

	DISK DRIVE REVENUES, BY SHIPMENT DESTINATION ($M)									
	1998 Revenues		Forecast							
			1999		2000		2001		2002	
	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW
U.S. Manufacturers										
Distributor	.8	1.7	.9	1.8	.6	1.0	1.3	1.7	2.8	4.0
OEM/Integrator	--	--	.5	2.1	1.9	4.7	7.5	15.3	12.7	24.2
TOTAL U.S. REVENUES	.8	1.7	1.4	3.9	2.5	5.7	8.8	17.0	15.5	28.2
Non-U.S. Manufacturers										
Distributor	12.0	21.8	14.6	26.5	18.8	33.3	23.5	40.1	26.1	43.1
OEM/Integrator	7.1	12.9	8.6	15.6	10.2	19.1	13.4	23.1	15.0	25.4
TOTAL NON-U.S. REVENUES	19.1	34.7	23.2	42.1	29.0	52.4	36.9	63.2	41.1	68.5
Worldwide Recap										
TOTAL WORLDWIDE REVENUES	19.9	36.4	24.6	46.0	31.5	58.1	45.7	80.2	56.6	96.7
OEM Average Price ($000)		.297		.226		.183		.123		.095

TABLE 50

CARD FORMAT RIGID DISK DRIVES

UNIT SHIPMENT SUMMARY

	DISK DRIVE UNIT SHIPMENTS, BY SHIPMENT DESTINATION (000)									
	1998 Shipments		Forecast							
			1999		2000		2001		2002	
	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW
U.S. Manufacturers										
Distributor	3.5	7.5	4.0	8.0	3.0	5.0	15.0	20.0	45.0	65.0
OEM/Integrator	--	--	5.0	20.0	22.0	55.0	105.0	215.0	215.0	410.0
TOTAL U.S. SHIPMENTS	3.5	7.5	9.0	28.0	25.0	60.0	120.0	235.0	260.0	475.0
Non-U.S. Manufacturers										
Distributor	35.8	65.1	48.0	87.0	65.0	115.0	85.0	145.0	100.0	165.0
OEM/Integrator	23.9	43.3	32.0	58.0	40.0	75.0	55.0	95.0	65.0	110.0
TOTAL NON-U.S. SHIPMENTS	59.7	108.4	80.0	145.0	105.0	190.0	140.0	240.0	165.0	275.0
Worldwide Recap										
TOTAL WORLDWIDE SHIPMENTS	63.2	115.9	89.0	173.0	130.0	250.0	260.0	475.0	425.0	750.0
Total Capacity (Terabytes)	32.1	58.7	44.6	84.8	69.3	130.5	151.0	273.5	331.7	586.2
Cumulative Shipments (Units in thousands)										
WORLDWIDE TOTAL	234.8	335.1	323.8	508.1	453.8	758.1	713.8	1,233.1	1,138.8	1,983.1

TABLE 51

CARD FORMAT RIGID DISK DRIVES

WORLDWIDE REVENUES ($M)

BREAKDOWN BY DISK DIAMETER

	1998 Revenues	Forecast							
		1999		2000		2001		2002	
	1.8"	1.8"	1.0"	1.8"	1.0"	1.8"	1.0"	1.8"	1.0"
U.S. MANUFACTURERS									
Distributor	1.7	1.8	--	1.0	--	--	1.7	--	4.0
OEM/Integrator	--	--	2.1	--	4.7	--	15.3	--	24.2
TOTAL U.S. REVENUES	1.7	1.8	2.1	1.0	4.7	--	17.0	--	28.2
NON-U.S. MANUFACTURERS									
Distributor	21.8	26.5	--	33.3	--	40.1	--	43.1	--
OEM/Integrator	12.9	15.6	--	19.1	--	23.1	--	25.4	--
TOTAL NON-U.S. REVENUES	34.7	42.1	--	52.4	--	63.2	--	68.5	--
WORLDWIDE RECAP									
Distributor	23.5	28.3	--	34.3	--	40.1	1.7	43.1	4.0
	-19.2%	+20.4%	--	+21.2%	--	+16.9%	--	+7.5%	+135.3%
OEM/Integrator	12.9	15.6	2.1	19.1	4.7	23.1	15.3	25.4	24.2
	--	+20.9%	--	+22.4%	+123.8%	+20.9%	+225.5%	+10.0%	+58.2%
Total Revenues	36.4	43.9	2.1	53.4	4.7	63.2	17.0	68.5	28.2
	+20.9%	+20.6%	--	+21.6%	+123.8%	+18.4%	+261.7%	+8.4%	+65.9%
ANNUAL SHARE, BY DIAMETER	100.0%	95.5%	4.5%	92.0%	8.0%	78.9%	21.1%	70.9%	29.1%

TABLE 52

CARD FORMAT RIGID DISK DRIVES

WORLDWIDE SHIPMENTS (000)

BREAKDOWN BY DISK DIAMETER

	1998 Shipments	Forecast							
		1999		2000		2001		2002	
	1.8"	1.8"	1.0"	1.8"	1.0"	1.8"	1.0"	1.8"	1.0"
U.S. MANUFACTURERS									
Distributor	7.5	8.0	--	5.0	--	--	20.0	--	65.0
OEM/Integrator	--	--	20.0	--	55.0	--	215.0	--	410.0
TOTAL U.S. SHIPMENTS	7.5	8.0	20.0	5.0	55.0	--	235.0	--	475.0
NON-U.S. MANUFACTURERS									
Distributor	65.1	87.0	--	115.0	--	145.0	--	165.0	--
OEM/Integrator	43.3	58.0	--	75.0	--	95.0	--	110.0	--
TOTAL NON-U.S. SHIPMENTS	108.4	145.0	--	190.0	--	240.0	--	275.0	--
WORLDWIDE RECAP									
Distributor	72.6	95.0	--	120.0	--	145.0	20.0	165.0	65.0
	-35.5%	+30.9%	--	+26.3%	--	+20.8%	--	+13.8%	+225.0%
OEM/Integrator	43.3	58.0	20.0	75.0	55.0	95.0	215.0	110.0	410.0
	--	+33.9%	--	+29.3%	+175.0%	+26.7%	+290.9%	+15.8%	+90.7%
Total Shipments	115.9	153.0	20.0	195.0	55.0	240.0	235.0	275.0	475.0
	+.4%	+32.0%	--	+27.5%	+175.0%	+23.1%	+327.3%	+14.6%	+102.1%
ANNUAL SHARE, BY DIAMETER	100.0%	88.5%	11.5%	78.1%	21.9%	50.6%	49.4%	36.7%	63.3%
TOTAL CAPACITY (Terabytes)	58.7	78.0	6.8	111.8	18.7	156.0	117.5	206.3	380.0

TABLE 53

CARD FORMAT RIGID DISK DRIVES

WORLDWIDE PRICE PER MEGABYTE ($/MB)

DISK DIAMETER	1998	Forecast 1999	Forecast 2000	Forecast 2001	Forecast 2002
Distributor					
1.8"	.65	.59	.50	.42	.34
1.0"	--	--	--	.17	.07
Distributor Average	.65	.59	.50	.40	.26
OEM/Integrator					
1.8"	.57	.52	.44	.37	.30
1.0"	--	.30	.25	.14	.07
OEM/Integrator Average	.57	.48	.38	.22	.12

Note: Price per megabyte calculations represent estimated total sales revenues for each product type divided by the total yearly shipped capacity of all drives of that type.

TABLE 54

CARD FORMAT RIGID DISK DRIVES

MARKET SHARE SUMMARY
Worldwide Shipments of Noncaptive Disk Drives

	1998 Net Shipments							
	To United States Destinations				Worldwide			
	Units (000)			%	Units (000)			%
Drive Manufacturers	1.8"	1.0"	Total		1.8"	1.0"	Total	
Calluna Technology	59.7	--	59.7	94.5	108.4	--	108.4	93.5
Integral Peripherals	3.5	--	3.5	5.5	7.5	--	7.5	6.5
Other U.S.	--	--	--	--	--	--	--	--
Other Non-U.S.	--	--	--	--	--	--	--	--
TOTAL	63.2	--	63.2	100.0	115.9	--	115.9	100.0

HIGH CAPACITY FLEXIBLE DISK DRIVES

HIGH CAPACITY FLEXIBLE DISK DRIVES

Coverage

Examples of flexible disk drives in this group include:

3.5" flexible disk drives

Alps Electric	HiFD
Caleb Technology	UHD 144
Imation	SuperDisk
Iomega	Zip 100, Zip 250, Notebook Zip 100*
Matsushita Communication Ind.	Zip 100
Matsushita-Kotobuki Electronics	LKM-F934, LKM-FB34-1*
Mitsubishi Electric	MF 357G, MF 357H*
NEC	FZ 110A (Zip 100)
O.R. Technology	FD-2120A*, FD-3120A
Sony	HiFD SFD200-1, HiFD SFD20H-1*
TEAC	HiFD FD-200K, HiFD FD-07*

Less than 2" flexible disk drives

Iomega	Clik! Internal*, Clik! PC Card*

*12.7 millimeters height, or less

The flexible disk drives currently included in this product group all have capacities of at least 40 megabytes. The functional and physical characteristics of these products are varied, and are individually discussed below. Unfortunately, there has been no general industry agreement on media interchange standards, and most of the high capacity floppy drives announced to date are incapable of interchanging diskettes with drives of other types, except for the downward compatibility with lower capacity standard floppy drives claimed by some manufacturers of high capacity 3.5" drives.

Zip drives: A significant new entry in the 3.5" high capacity floppy drive market appeared in 1994 with the Iomega announcement of the "Zip" 100 megabyte drive. After participating in the 21 megabyte floptical market and in the Optics Research joint program to develop a higher capacity version of the drive, Iomega undertook its own development program to develop a drive with the lowest possible cost.

The Zip drive dispensed with backward compatibility, and started shipments in March, 1995, with 100 megabytes at an initial end user price of $199, since reduced to $99 or less for internal models. Zip sales were initially only in the PC aftermarket, but the sales pattern has evolved into more than half direct sales to system manufacturers. Thin models with 100 megabyte capacities designed for notebook computers have been added, initially 15 millimeters high, followed by 12.7 millimeters in 1998. Apparently prompted by Sony's introduction of the 200 megabyte HiFD drive, Iomega made a 250 megabyte version of the 1" high Zip drive available in late 1998. After initially manufacturing the Zip drive at its factory in Roy, Utah, Iomega moved production to Penang, and granted manufacturing licenses to Matsushita Communication Industrial and NEC.

<u>SuperDisk (LS-120) drives</u>: Insite Peripherals achieved quick fame in the industry by announcing its trademarked "floptical" technology, a combination of optical tracking methods with conventional magnetic recording. Insite's floptical disk drives used a reflective servo pattern applied to the surface of 3.5" diskettes to achieve a diskette capacity of 21 megabytes in a one inch high form factor, with downward read/write compatibility for standard diskettes.

In 1992, Insite engaged Matsushita-Kotobuki Electronics to manufacture the drive on a contract basis, and also licensed the floptical technology to Iomega, which introduced drives compatible with Insite's in 1992, using Chinon as a contract manufacturing source. Iomega phased out of the floptical drive market in 1994, after finding a limited market for the product. In November, 1993, O.R. Computer System Pte. Ltd., a major Singapore distributor of personal computers and peripherals, acquired control of Insite Peripherals, changed the name to O.R. Technology in 1995, and continued to sell floptical 21 megabyte drives produced by MKE until phasing them out in 1996.

In 1995, a joint program for the LS-120, a 120 megabyte version of the 3.5" floptical disk drive developed by Optics Research, Inc., in Boulder, Colorado, was announced by three companies, with MKE manufacturing the drives, 3M (now Imation) manufacturing the metal powder diskettes, and Compaq Computer using the drives in personal computers. SuperDisk drives are backward compatible with 720 kilobyte, 1.2 megabyte and 1.44 megabyte floppies, with initial models in the standard form factor for one inch high 3.5" drives, later supplemented by 12.7 millimeter high models for the notebook computer market.

Mitsubishi Electric also manufactures and sells SuperDisk drives, and Imation and O.R. Technology resell drives produced through contract manufacturing arrangements. In the second half of 1997, the companies participating in the LS-120 drive program started using the term SuperDisk to describe the product.

HiFD disk drives: In October, 1997, Sony and Fuji Photo Film announced the HiFD 200 megabyte 3.5" drive, offering backward compatibility to standard 3.5" diskettes, with drives made by Sony and the metal powder diskette produced by Fuji Photo Film. TEAC and Alps Electric have been added as drive licensees. The HiFD program attracted wide interest in the industry due to Sony's stature as a product innovator, and because the embedded servo recording technology to be used has the potential to achieve drive manufacturing costs which could be lower than the cost of the SuperDisk drive and might rival those of the Zip drive.

The original announcement predicted drive availability in Spring, 1998, subsequently delayed until late 1998, but the actual introduction was a disaster. A high percentage of the limited quantity of HiFD drives Sony shipped in late 1998 had reliability problems, and the market introduction was quickly put on hold. Sony has continued to display the HiFD at trade shows and has indicated that the product will be reintroduced in the Autumn of 1999.

UHD144 drive: Caleb Technology was formed in 1995 by one of the key managers from the Iomega drive development program in Boulder, Colorado, with extensive experience in optical and magnetic disk drives, including the 20 megabyte floptical and later 120 megabyte floppy drives. Originally planning a 200 megabyte backward compatible floppy, Caleb eventually announced a 144 megabyte drive model in October, 1997. Kabool Electronics, a subsidiary of the Korean Kabool textiles group, owns a major interest in Caleb, and the original founder is no longer in a management role. Caleb currently plans to initiate drive production through a contract manufacturing arrangement in Singapore, and the firm is working on an additional round of financing.

Pro-FD: Samsung Electro-Mechanics, a member of the Korean Samsung group and a manufacturer of an extensive line of electronic components, took over the flexible disk drive product lines previously manufactured by Samsung Electronics in 1995, and has sharply increased shipments of standard low capacity floppy drives through a program of active sales and aggressive pricing. In the Autumn of 1998, the firm announced the Pro-FD, a 3.5" floppy drive with 123 megabytes capacity, with a unique ability to write the servo tracks on the disks it uses. Currently, the company hopes to start shipments by the end of 1999.

UHC disk drives: Swan Instruments, a California manufacturer of test equipment for the disk drive industry, announced a combination fixed/removable floppy drive with capacities over 100 megabytes in 1994, using technology licensed from Antek Peripherals, which also granted a license to Mitsumi Electric. After a dispute over licensing terms, the two companies announced an agreement in 1996, under which both companies would have the right to manufacture drives in accordance with a common interchange standard, with Mitsumi initially concentrating on establishing manufacturing capability for the drives, and Swan establishing manufacturing arrangements for diskettes. After extensive delays, Mitsumi Electric dropped the program and Swan Instruments has gone out of business.

Clik!: After preannouncing the idea of a miniaturized, low cost flexible disk drive in 1996 under the "n*hand" name, Iomega made the specific announcement of the Clik! 40 megabyte drive using a 47 millimeter disk at Fall Comdex in 1997. Iomega has widely publicized the $9.95 suggested retail price for the Clik! disk, but has avoided discussing the OEM price level for the drive, the most important variable in obtaining wide utilization. Iomega has licensed Citizen Watch, NEC and Matsushita Communication Industrial to manufacture and sell the Clik! drive, but none have yet announced specific products.

With its initial production underway in 1999, Iomega is undertaking a missionary selling program to develop interest among manufacturers of products considered to be appropriate markets for Clik!, including digital cameras, handheld PCs, personal digital assistants, smart phones, global positioning systems, etc. In a further effort to stimulate distribution sales for Clik!, Iomega introduced a "mobile drive" aftermarket Clik! model in early 1999, followed by a PC Card version for initial shipments in the third quarter of 1999.

Iomega Bernoulli principle drives: Iomega's 5.25" disk drives, which were phased out in 1997, used the Bernoulli effect to control head/disk spacing. These were high performance drives, using flexible disks in a removable cartridge, and a sophisticated internal air flow system to maintain the proper position of the flexible disk relative to the recording head. A rotary voice coil magnetic head positioning system, in conjunction with an embedded servo, provides average seek times equivalent to those of many rigid disk drives.

Iomega started deliveries of the original 8" 10 megabyte Alpha-10 in September, 1982, followed by other 8" models. A 5 megabyte 5.25" drive was introduced in 1983, followed by a 21 megabyte half high model in 1986, a 44 megabyte version in 1989, a 90 megabyte model in 1991, a 150 megabyte model in 1992, and the 230 megabyte model, the last of the breed, in late 1994. The Bernoulli principle drives weren't able to stay competitive, because the drives' complexity made cost reduction impractical and it was difficult to use Bernoulli technology in the 3.5" form factor.

Market status

Despite a remarkable level of product announcements, promotion activity and press coverage, the only high capacity floppy drives currently in production are the SuperDisk, with 120 megabytes and backward compatibility, the Zip 100 and 250 megabyte models, and the 40 megabyte Clik!. Shipments continue to grow, reaching 12.7 million drives in 1998, an increase of 58.4% over the previous year, with 18.7 million units forecasted for 1999. Sales revenues grew 57% in 1998, to $846.8 million, and are projected to reach $944.8 million in 1999, up only 11.6%, due to a changing product mix and aggressive price competition.

Although shipments of high capacity floppy drives have been increasing every year, the rate of increase is clearly less than the drive manufacturers had originally hoped for. High capacity floppy drives provide a capability which only a minority of PC users find necessary, and the drives' prices are several times higher than prices for standard 1.44 megabyte floppy drives, thus preventing personal computer manufacturers from considering general replacement of low capacity floppy drives. The OEM average price for high capacity floppy drives was $65 in 1998, with the 1999 level projected at $46. Since the OEM average price for 1.44 megabyte floppy drives is about $11 in 1999, the market for high capacity floppy drives is essentially limited to PC build-to-order or aftermarket customers who have a specific functional need for the additional capacity.

The last of the 21 megabyte original floptical drives was shipped in 1996. Although the 21 megabyte floptical drive found a market in a variety of specialized applications, broader sales throughout the computer industry were held down due to drive price levels perceived as too high by both personal computer manufacturers and most end users, and a drive capacity not high enough to attract a broad market.

Iomega pioneered the current high capacity floppy drive market with the 100 megabyte Zip drive, establishing a strong lead in shipments which continues today. However, the competitive situation has become more complex, with the addition of more brands and suppliers. Iomega licensed Matsushita Communication Industrial and NEC to make Zip drives, and both are in production. The LS-120 consortium started with production by Matsushita-Kotobuki Electronics in 1996, supplemented by drives made by Mitsubishi Electric. Drives produced on a contract manufacturing basis and sold by Imation have received extensive promotion for the SuperDisk label.

Despite numerous delays, it is considered likely that the product mix in the high capacity floppy drive product group will gain new participants within the next six months. At least six additional announced manufacturers of high capacity floppy drives could start actual production operations during the coming year. It is the long-standing policy of DISK/TREND to avoid future forecasts of market share by company, and in this situation it would probably be impossible. The key difficulties in forecasting individual disk drive formats are the uncertainties regarding when each new type of drive will actually be produced in quantity, similar questions involving media, and the unknown pricing policies of key drive manufacturers.

High capacity floppy drive applications with desktop personal computers dominated shipments in 1998, with 78.5% of overall shipments for the product group. Consumer applications, including game and hobby computers, accounted for 15.6% of shipments. With the start of 12.7 millimeter high drive shipments in 1997, portable computer applications used 3.6% of 1998 worldwide shipments. By 2002, high capacity floppy drive shipments are expected to consist of both 3.5" drives plus miniaturized models such as the Iomega Clik!, which will enhance the share expected for specialized markets. Desktop personal computers are forecasted to remain far in the lead with 67.0% of 2002 shipments, followed by consumer markets with 16.8% and portable computers with 9.7%, but other specialized applications are forecasted at 6.2%.

Iomega has continued to maintain leadership in worldwide noncaptive drive shipments, with 9.5 million Zip drives in 1998, but the firm's share was down to 74.5% of the total. Matsushita Electronics was in second place with 8.6% and Mitsubishi Electric in third position with 7.8%, the result of growing shipments of SuperDisk drives by both companies.

Marketing trends

Despite competition from other types of disk drives and a lack of interchange standards within the high capacity floppy product group, continued overall growth in shipments is projected. The worldwide total for 2002 is forecasted at 34.3 million drives, an average annual increase for the 2000-2002 period of 22.4%. Sales revenues are projected to increase during that period by an average of only 4.4%, as continuing changes in product mix and increasing levels of competition hold prices down.

The sales outlook for the Iomega Clik! drive must be considered highly speculative, depending on the receptivity of entirely new markets such as digital cameras and other specialized applications, the potential market size is significant. The current DISK/TREND forecasts for such miniaturized floppy drives are considered conservative, and the actual shipments could be much higher by 2002, depending on the speed and degree of market acceptance, the appearance or absence of effective competitive storage devices, plus the availability and pricing of drives and media.

The 1999 DISK/TREND forecast assumes a modest start for the Iomega Clik! in 1999 with 300,000 drives, a major portion of which will be sold in the computer aftermarket. As manufacturers of digital cameras and other devices gradually introduce products using these drives, shipments are forecasted to grow to 5.4 million drives in 2002.

3.5" high capacity floppy drives are expected to generate much larger shipments, based on the market penetration already demonstrated for these products and the size of available markets. By 2002, 3.5" drive shipments are expected to reach 28.8 million units, an average annual increase for the 2000-2002 period of 16.3%.

There has been extensive speculation about the possibility that high capacity floppy drives would eventually replace standard 1.44 megabyte 3.5" floppy drives. DISK/TREND forecasts do not anticipate a major decline in shipments of low capacity floppy drives during the current forecast period. It is expected that the net effect of the availability of the current mixed bag of high capacity floppy drives will be to capture most of the growth available to the two types of floppy drives, while the growth pattern for low capacity floppy drives becomes negligible. The only thing which would undoubtedly increase the market penetration of high capacity floppy drives would be industry agreement on a single interchange standard for high capacity floppy drives -- an unlikely event.

The key reasons for the continued viability of 1.44 megabyte floppies are that a very large portion of the work being done on personal computers is simple word processing, for which standard floppies provide cost-effective backup and interchange capabilities, and the fact that the average OEM price for high capacity floppy drives is several times higher than the OEM price for low capacity floppy drives. The DISK/TREND projections are based on the expectation that word processing will still be the most widely used PC application in 2002, requiring only modest amounts of disk storage, and that the average OEM price difference between high capacity and low capacity floppy drives, although declining, will still be at approximately a 3 to 1 ratio.

It is expected that the market's reaction to the generation of 3.5" high capacity floppy drives now available, plus those expected in the near future, will be adequate to carry shipments for this product group to the much higher levels now projected. Several computer industry trends have combined to create this response.

The continuous increase in capacities for the fixed rigid disk drives used as the basic disk storage for all of today's personal computers has made many users nervous about their risks in failing to preserve their data by backing it up. For many of these users in both home and business applications, the high capacity floppy now provides an inexpensive alternative to buying a tape drive, and preserves the convenience offered by the random access capability of the disk drive. Many other users now have the functional need to keep individual projects offline to free space on their system's fixed disk drive, a pattern previously available only to users of high-end personal computers or workstations, at much higher cost.

The widespread usage of graphics and desktop publishing software, CD-ROM applications, games, and downloads from the Internet have inspired many additional computer users to seek affordable removable storage devices which are suitable to keep projects on individual disks, ready to be loaded into a drive when needed. High capacity 3.5" floppy drives are expected to capture a major part of the available market created by the above trends, while coexisting in a competitive marketplace alongside rigid disk cartridge drives, small magneto optical disk drives, CD-RW drives and tape cartridge drives.

At the moment, the key competitors are locked in a struggle for sales momentum, with SuperDisk advocates contending that backward compatibility is essential to market dominance, and Iomega saying "Not so!". If all competitive considerations were equal, including drive prices, it would be logical to expect PC manufacturers to choose a backward compatible high capacity floppy drive if used as a standard feature in a PC. This would be especially true in the case of notebook computers, where there is never space for two floppy drives.

However, in this contest the Zip drive had more than a year's head start, initially developing sales as an aftermarket add-on product, later supplemented by OEM adoptions by several personal computer manufacturers. Although the high capacity floppy drive field has already become a classic electronics industry standards war, the battlefield is now becoming even more complex with the addition of three currently announced additional high capacity floppy drive formats -- and the likelihood that some of them may actually be in production during the next six months. The destiny of participants in this marketplace during the next few years will be a messy standards conflict, with growth for some, extinction for others.

Technology trends

The two most important development objectives for 3.5" high capacity floppy disk drives will be increased diskette capacities beyond the current 100-250 megabytes, and to achieve design simplification needed for low manufacturing cost.

The head positioning systems used in these drives are critical to potential increases in capacity, as well as to keeping manufacturing costs to a minimum. The embedded servo technique used by all of the existing drives except the SuperDisk is similar to the method employed by most of the current generation rigid disk drives. The SuperDisk floptical optical tracking method is perhaps the most innovative approach, with obvious potential for greater capacity and low manufacturing costs. The reflective servo pattern is imprinted on the diskette as part of the media manufacturing process, and should increase the media manufacturing cost only slightly when high shipment levels are achieved.

It appears that the embedded servo design, initially used in high capacity floppies with Iomega's Zip drive, has intrinsic cost advantages, when compared with the SuperDisk design. Both types of drives can utilize components designed for rigid disk drives produced at very high production volumes, and therefore available at low costs. The challenge for the engineers working with the floptical design will be to reduce the manufacturing cost of the drive, no small challenge when the requirements of the optical tracking method and backward compatibility are considered, both of which contribute to an increased parts count.

None of the interesting technical developments in this field will see wide application unless producible at low cost. This is not going to be easy, since these drives require sophisticated head positioning systems, multifunction heads, high density encoding schemes, error correction capability, high reliability and embedded controllers. Furthermore, the media must be priced low enough to avoid buyer resistance, while still offering long life, adequate durability and easy handling. It's definitely a difficult development task, but without low costs these drives will occupy only a small market niche.

Forecasting assumptions

1. No agreement on an industry-wide standard for high capacity 3.5" floppy drives will be achieved through 2002, and adequate production of 3.5" high capacity floppy drives will be available to satisfy demand.

2. Although the higher production levels for 3.5" high capacity floppy drives projected for future years will lower the pricing differential compared to 1.44 megabyte 3.5" drives, high capacity 3.5" drives will still be priced

about 3 times higher at the OEM level than 1.44 megabyte drives in 2002, and will not be able to replace them as the basic floppy drive used with the majority of personal computers.

3. Miniaturized high capacity floppy drives smaller than 2" will establish modest aftermarket sales in 1999-2000, with growth after 2000 dominated by OEM shipments for digital cameras and other mobile devices.

TABLE 55

HIGH CAPACITY FLEXIBLE DISK DRIVES

REVENUE SUMMARY

	DISK DRIVE REVENUES, BY SHIPMENT DESTINATION ($M)									
	1998 Revenues		Forecast 1999		2000		2001		2002	
	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW
U.S. Manufacturers										
Distributor	191.5	319.3	191.8	316.4	176.1	286.8	151.8	243.5	125.8	200.2
OEM/Integrator	224.9	321.4	216.5	311.7	228.6	336.7	231.5	351.8	236.8	361.7
TOTAL U.S. NONCAPTIVE	416.4	640.7	408.3	628.1	404.7	623.5	383.3	595.3	362.6	561.9
TOTAL U.S. REVENUES	416.4	640.7	408.3	628.1	404.7	623.5	383.3	595.3	362.6	561.9
Non-U.S. Manufacturers										
Captive	--	.4	--	2.1	.9	5.3	1.9	8.2	2.7	9.4
Distributor	122.5	145.6	170.6	201.4	206.1	267.9	213.9	293.3	201.0	288.0
OEM/Integrator	39.9	60.1	64.4	113.2	81.8	138.2	97.9	172.5	119.5	214.0
TOTAL NON-U.S. REVENUES	162.4	206.1	235.0	316.7	288.8	411.4	313.7	474.0	323.2	511.4
Worldwide Recap										
TOTAL WORLDWIDE REVENUES	578.8	846.8	643.3	944.8	693.5	1,034.9	697.0	1,069.3	685.8	1,073.3
OEM Average Price ($000)		.065		.046		.037		.030		.027

TABLE 56

HIGH CAPACITY FLEXIBLE DISK DRIVES

UNIT SHIPMENT SUMMARY

DISK DRIVE UNIT SHIPMENTS, BY SHIPMENT DESTINATION (000)

	1998 Shipments		Forecast 1999		Forecast 2000		Forecast 2001		Forecast 2002	
	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW
U.S. Manufacturers										
Distributor	2,736.0	4,561.0	3,570.0	5,845.0	4,060.0	6,555.0	4,210.0	6,695.0	3,910.0	6,190.0
OEM/Integrator	3,460.0	4,945.0	4,810.0	6,955.0	6,015.0	9,015.0	7,095.0	11,185.0	8,165.0	12,970.0
TOTAL U.S. NONCAPTIVE	6,196.0	9,506.0	8,380.0	12,800.0	10,075.0	15,570.0	11,305.0	17,880.0	12,075.0	19,160.0
TOTAL U.S. SHIPMENTS	6,196.0	9,506.0	8,380.0	12,800.0	10,075.0	15,570.0	11,305.0	17,880.0	12,075.0	19,160.0
Non-U.S. Manufacturers										
Captive	--	2.0	--	20.0	10.0	60.0	25.0	110.0	40.0	140.0
Distributor	1,935.0	2,330.0	3,030.0	3,650.0	3,765.0	4,895.0	4,375.0	6,005.0	4,615.0	6,630.0
OEM/Integrator	620.0	920.0	1,320.0	2,290.0	2,210.0	3,765.0	3,190.0	5,815.0	4,480.0	8,340.0
TOTAL NON-U.S. SHIPMENTS	2,555.0	3,252.0	4,350.0	5,960.0	5,985.0	8,720.0	7,590.0	11,930.0	9,135.0	15,110.0
Worldwide Recap										
TOTAL WORLDWIDE SHIPMENTS	8,751.0	12,758.0	12,730.0	18,760.0	16,060.0	24,290.0	18,895.0	29,810.0	21,210.0	34,270.0
Cumulative Shipments (Units in millions)										
WORLDWIDE TOTAL	18.1	26.9	30.8	45.6	46.9	69.9	65.7	99.7	87.0	134.0

TABLE 57

HIGH CAPACITY FLEXIBLE DISK DRIVES

WORLDWIDE REVENUES ($M)

BREAKDOWN BY DISK DIAMETER

	1998 Revenues	Forecast							
		1999		2000		2001		2002	
	3.5"	3.5"	< 2"	3.5"	< 2"	3.5"	< 2"	3.5"	< 2"
U.S. MANUFACTURERS									
Distributor	319.3	309.4	7.0	268.6	18.2	219.8	23.7	178.8	21.4
OEM/Integrator	321.4	309.4	2.3	326.5	10.2	325.2	26.6	320.7	41.0
TOTAL U.S. REVENUES	640.7	618.8	9.3	595.1	28.4	545.0	50.3	499.5	62.4
NON-U.S. MANUFACTURERS									
Captive	.4	2.1	--	5.3	--	8.2	--	9.4	--
Distributor	145.6	201.4	--	266.2	1.7	286.3	7.0	278.1	9.9
OEM/Integrator	60.1	113.2	--	136.2	2.0	160.4	12.1	183.9	30.1
TOTAL NON-U.S. REVENUES	206.1	316.7	--	407.7	3.7	454.9	19.1	471.4	40.0
WORLDWIDE RECAP									
Captive	.4	2.1	--	5.3	--	8.2	--	9.4	--
	--	+425.0%	--	+152.4%	--	+54.7%	--	+14.6%	--
Distributor	464.9	510.8	7.0	534.8	19.9	506.1	30.7	456.9	31.3
	+34.4%	+9.9%	--	+4.7%	+184.3%	-5.4%	+54.3%	-9.7%	+2.0%
OEM/Integrator	381.5	422.6	2.3	462.7	12.2	485.6	38.7	504.6	71.1
	+97.6%	+10.8%	--	+9.5%	+430.4%	+4.9%	+217.2%	+3.9%	+83.7%
Total Revenues	846.8	935.5	9.3	1,002.8	32.1	999.9	69.4	970.9	102.4
	+57.1%	+10.5%	--	+7.2%	+245.2%	-.3%	+116.2%	-2.9%	+47.6%
ANNUAL SHARE, BY DIAMETER	100.0%	99.1%	.9%	97.0%	3.0%	93.6%	6.4%	90.6%	9.4%

TABLE 58

HIGH CAPACITY FLEXIBLE DISK DRIVES

WORLDWIDE SHIPMENTS (000)

BREAKDOWN BY DISK DIAMETER

	1998 Shipments	Forecast							
		1999		2000		2001		2002	
	3.5"	3.5"	< 2"	3.5"	< 2"	3.5"	< 2"	3.5"	< 2"
U.S. MANUFACTURERS									
Distributor	4,561.0	5,625.0	220.0	5,970.0	585.0	5,785.0	910.0	5,260.0	930.0
OEM/Integrator	4,945.0	6,875.0	80.0	8,590.0	425.0	9,855.0	1,330.0	10,690.0	2,280.0
TOTAL U.S. SHIPMENTS	9,506.0	12,500.0	300.0	14,560.0	1,010.0	15,640.0	2,240.0	15,950.0	3,210.0
NON-U.S. MANUFACTURERS									
Captive	2.0	20.0	--	60.0	--	110.0	--	140.0	--
Distributor	2,330.0	3,650.0	--	4,840.0	55.0	5,725.0	280.0	6,180.0	450.0
OEM/Integrator	920.0	2,290.0	--	3,680.0	85.0	5,175.0	640.0	6,570.0	1,770.0
TOTAL NON-U.S. SHIPMENTS	3,252.0	5,960.0	--	8,580.0	140.0	11,010.0	920.0	12,890.0	2,220.0
WORLDWIDE RECAP									
Captive	2.0	20.0	--	60.0	--	110.0	--	140.0	--
	--	+900.0%	--	+200.0%	--	+83.3%	--	+27.3%	--
Distributor	6,891.0	9,275.0	220.0	10,810.0	640.0	11,510.0	1,190.0	11,440.0	1,380.0
	+33.3%	+34.6%	--	+16.5%	+190.9%	+6.5%	+85.9%	-.6%	+16.0%
OEM/Integrator	5,865.0	9,165.0	80.0	12,270.0	510.0	15,030.0	1,970.0	17,260.0	4,050.0
	+103.3%	+56.3%	--	+33.9%	+537.5%	+22.5%	+286.3%	+14.8%	+105.6%
Total Shipments	12,758.0	18,460.0	300.0	23,140.0	1,150.0	26,650.0	3,160.0	28,840.0	5,430.0
	+58.4%	+44.7%	--	+25.4%	+283.3%	+15.2%	+174.8%	+8.2%	+71.8%
ANNUAL SHARE, BY DIAMETER	100.0%	98.5%	1.5%	95.4%	4.6%	89.5%	10.5%	84.3%	15.7%

TABLE 59

HIGH CAPACITY FLEXIBLE DISK DRIVES

APPLICATIONS SUMMARY
Percentage of Worldwide Shipments

APPLICATION	1998 Estimate Units (000)	1998 Estimate %	2002 Projection Units (000)	2002 Projection %
SPECIALIZED HIGH PERFORMANCE Supercomputers, video and high end imaging	6.4	.1	--	--
MAINFRAME SYSTEMS General purpose	--	--	--	--
NETWORK/MIDRANGE SYSTEMS Midrange systems, network servers and workstations	149.3	1.2	102.8	.3
DESKTOP PERSONAL COMPUTERS Business and professional, single user	10,013.8	78.5	22,960.9	67.0
CONSUMER COMPUTERS Desktop PCs, game, and hobby computers	1,990.2	15.6	5,757.4	16.8
PORTABLE COMPUTERS Notebook and smaller mobile computers	458.0	3.6	3,324.2	9.7
OTHER APPLICATIONS	140.3	1.0	2,124.7	6.2
Total	12,758.0	100.0	34,270.0	100.0

TABLE 60

HIGH CAPACITY FLEXIBLE DISK DRIVES

MARKET SHARE SUMMARY
Worldwide Shipments of Noncaptive Disk Drives

	1998 Net Shipments					
	To United States Destinations			Worldwide		
	Units (000)		%	Units (000)		%
Drive Manufacturers	3.5"	Total		3.5"	Total	
Iomega	6196.0	6196.0	70.8	9506.0	9506.0	74.5
Matsushita Elec. Ind.	990.0	990.0	11.3	1100.0	1100.0	8.6
Mitsubishi Electric	725.0	725.0	8.3	990.0	990.0	7.8
Matsushita Comm. Ind.	390.0	390.0	4.5	590.0	590.0	4.6
NEC	450.0	450.0	5.1	570.0	570.0	4.5
Other U.S.	--	--	--	--	--	--
Other Non-U.S.	--	--	--	--	--	--
TOTAL	8751.0	8751.0	100.0	12756.0	12756.0	100.0

LOW CAPACITY FLEXIBLE DISK DRIVES

1999 DISK/TREND REPORT

LOW CAPACITY FLEXIBLE DISK DRIVES

Coverage

Examples of low capacity flexible disk drives in this group include:

8" disk diameter

Y-E Data	YD-180

5.25" disk diameter: 1.2 megabytes

Y-E Data	YD-380B

5.25" disk diameter: 2.4 megabytes

Y-E Data	YD-801

3.5" disk diameter: 1.2 megabytes

TEAC	FD-235GF
Y-E Data	YD-686C

3.5" disk diameter: 1.44 megabytes

Alps Electric	DF 354H
Citizen	OSDA, X1DE*
Matsushita Communication Ind.	JU-227A*, JU-257
Mitsubishi Electric	MF 355F, MF 355H*
Mitsumi Electric	D 353F3*, D 359M3
NEC	FD 1231T, FD 1238T*
Samsung Electro-Mechanics	SFD-321B, SFD-321S*
Sony	MPF720*, MPF920
TEAC	FD-235HF, FD-05HG*
Y-E Data	YD-701B, YD-702J*

*12.7 millimeters height, or less

The first commercial flexible disk drive, used only to load microcode for a mainframe disk drive controller, was an 8" drive shipped by IBM in 1971. However, IBM's 33FD 8" floppy drive, first shipped in 1973, established an industry de facto standard, setting off a rush of companies vying to establish flexible disk drive production. 26 years later, one manufacturer is still producing 8" floppy drives.

The basic standards for physical size and recording format for 5.25" floppy drives were created by Shugart Associates' 1976 introduction of the SA 400, the original minifloppy. Early growth in small microcomputer systems inspired several innovative one sided 5.25" drives, and two sided 5.25" floppy drives became a reality in 1978. The current industry recording format was established in 1982, when 1.2 megabyte two sided 5.25" drives were first shipped by Y-E Data, designed to a standard coordinated by Nippon Telephone and Telegraph. IBM's 1984 introduction of the PC AT, using Y-E Data's 1.2 megabyte drive, stampeded the market into rapid worldwide usage of the 1.2 megabyte 5.25" format, which for several years accounted for most of the industry's shipments of 5.25" floppy drives.

The only type of microfloppy currently remaining in the low capacity floppy drive product group is the 3.5" format, which has evolved into the industry standard. All of the other microfloppy formats in the 2" to 4" diameter range which were introduced during the last 14 years have been phased out. All 3.5" drives are derived from the Sony microfloppy first shipped in 1982, with modifications to achieve logical file organization similar to the larger diskette drives which preceded it in the market.

The last of the 3.5" drives with capacities of one megabyte or less, most of which were designed to maintain logical file compatibility with 5.25" drives, were phased out during the last few years. 1.2 and 1.44 megabyte 3.5" drives were announced in 1985, and are intended for use with the high density media originally proposed by Sony, which operates at up to 17,434 BPI, and uses the 135 TPI standard of today's production drives. 1.2 megabyte 3.5" drives are compatible with NEC drives originally used with personal computers in the domestic Japanese market. After the adoption of 1.44 megabyte drives by IBM in April, 1987, for the PS/2 systems, most major manufacturers of microfloppy drives added drives with the same capacity.

Manufacturers of 3.5" floppy drives have also made the transition from the earlier 41.3 millimeter high drives ("half high", in 5.25" drive terms) to the 25.4 millimeter (one inch) high drives pioneered by Citizen in 1984. Citizen's floppy drive packaging innovations prompted many companies to follow the firm's introduction of thinner drives in the 17-19 millimeter (3/4 inch) high range in 1989 and 15 millimeters in 1991. This trend culminated in TEAC's introduction of 12.7 millimeter (one half inch) high drives for shipment later in 1991 -- which, in turn, prompted many other drive manufacturers to join the movement to half inch high floppy drives. Citizen did not match the 12.7 millimeter height, but lowered the height on its later models to 10.9 millimeters.

The 3" microfloppy format which was produced in quantity for several years has lost all of its original adherents including the last manufacturer, Matsushita Electronic Components, and is now out of production. 2" drives, in a data recording version of a video camera floppy, were produced during recent years by Sony, but found a limited market. Mitsubishi Electric has shown a miniaturized 1.44 megabyte floppy drive in a PC Card format at trade shows during the last few years, but has also found resistance from buyers concerned with interchange considerations and a market potential too small to justify the start of production.

Market status

For several years, most manufacturers of standard 1.44 megabyte floppy drives have believed that shipments would soon peak, due to competitive inroads from other data storage devices and increasing usage of "thin clients", without storage devices. However, the anticipated slowdown did not occur in 1998, and the worldwide total of 113.4 million drives provided a 15.3% increase over the previous year. However, 1999 overall shipments of low capacity floppy drives appear to be somewhat weaker, with a DISK/TREND forecast of 120.2 million, up only 6.0%. Average unit prices have continued to decline for several years, forcing total sales revenues down. That trend continued in 1998, with worldwide sales revenues of $1.6 billion, down 5.0%, and 1999 projected at $1.5 billion, a decline of 7.9%.

The reasons for the continuing price decline are pressure from system manufacturers for the lowest possible price, extensive product redesign for cost reduction, and the movement of most Japanese floppy drive manufacturing to offshore production sites with lower costs. The average OEM price for all 3.5" floppy drives was $59 in 1988, $51 in 1989, $46 in 1990, $42 in 1991, $38 in 1992, $34 in 1993, $27 in 1994, $22 in 1995, $20 in 1996, $16 in 1997, and $14 in 1998. In 1999 the overall OEM average unit price for 3.5" floppy drives is expected to be $12. These average unit prices include all types of 3.5" low capacity floppy drives, including thin models for notebook computers, which typically carry higher price levels. Standard one inch high drives will be a dollar or two lower than the above average unit prices.

Several computer industry trends are contributing to the decline in growth rate for low capacity floppy drives. For many years, the majority of personal computers used in business applications utilized both 3.5" and 5.25" floppy drives to facilitate interchange of 5.25" diskettes with older personal computers. However, shipments of 5.25" floppy drives declined rapidly after 1992, as the percentage of PC buyers who needed 5.25" floppy drives for interchange dropped off, and only modest shipments for 5.25" drives remain. The wide scale utilization of CD-ROM drives with personal computers has eliminated the need for floppy drives to read purchased software for some users who have no other functional requirement for a floppy. The gradual trend to delete the 3.5" floppy drive from many notebook computer models has also reduced the drive growth rate. These factors have slowed the overall growth rate for low capacity floppy drive shipments in the last few years, and the current period will be affected by these trends, plus the negative influences of some additional displacement by high capacity floppy drives and early inroads by "network computers", using neither rigid nor flexible disk drives.

Floppy drives less than one inch high initially became a growth product for notebook computer applications, but that trend is now slowing down, with the tendency of computer manufacturers to leave the floppy drive out of some notebook computer models, combined with the negative influence of generally higher prices for thin floppy drives. One inch high (25.4 millimeter) 3.5" floppy drives became the dominant form factor several years ago, and have shown continuing strength in the face of competition from new drives in thinner physical formats. Intense competition has come from drives with smaller heights -- initially 19 millimeters, then 17 millimeters, 15 millimeters, 12.7 millimeters, and eventually down to 10.9 millimeters. 3.5" floppy disk drives in packages 12.7 millimeters thick now constitute most of the 3.5" drive shipments for models less than one inch high, which collectively provided 13.1% of the 1998 3.5" overall total, with 12.7 millimeter drive shipments expected to rise to only 14.1% of the overall 1999 total.

Desktop personal computers for business and professional use utilized 63.0% of 1998 shipments, and are projected to decline slightly to a projected

59.7% in 2002, as consumer computers increase to 24.3% of worldwide 2002 shipments, up from 22.7% in 1998. Portable computer applications, with 13.6% of 1998 unit shipments, are projected at 15.9% of 2002 shipments.

Mitsumi Electric was again the leader in noncaptive shipments, capturing 21.8 million 3.5" drives, 19.5% of the worldwide total. Matsushita Communication Industrial moved up to second place with 18.0 million 3.5" drives, 16.1% of the total, and TEAC was third with 17.2 million units, shipping mostly 3.5" drives, with a modest quantity of 5.25" drives, for 15.4% of the worldwide total.

Marketing trends

The shipment peak for low capacity floppy drives appears to be imminent, due to changing patterns of usage and the competitive impact of high capacity floppies. Following a modest increase in 2000, the current DISK/TREND forecast anticipates a peak in 2001 with 122.7 million drives, followed by a decline of 2.4% in 2002, with shipments of 119.7 million units. The pattern of declining overall sales revenues is expected to continue, with total sales revenues for 2002 projected at $1.2 billion, an average drop of 8.2% per year during 2000-2002.

The sinking sales revenues for low capacity floppy drives has been caused by declining average unit prices, combined with product mix changes, as sales have dropped for several types of drives with higher prices. The situation continues to change. The 5.25" floppy drive is almost gone, along with the downward influence on revenues caused for several years by falling sales of the relatively high priced 5.25" drives. On the other hand, the tendency of computer manufacturers to design lightweight notebook computers without floppy drives is starting to reduce shipments of thin 3.5" floppy drive models. Furthermore, the long-term shipment growth for the industry's basic one inch high 3.5" floppy drives is expected to be held down by competition from high capacity floppy drives.

There is a consensus among participants in the low capacity floppy drive business that noncaptive average unit prices for mainstream one inch high 3.5" drives will continue to decline. Noncaptive drive price levels are expected to continue the long-term trend to lower levels, as the result of intense competition between leading Japanese floppy drive manufacturers and the lower costs these manufacturers are achieving as they fine-tune the manufacturing facilities which have been established during recent years in the Philippines, Malaysia, Thailand, and China. The overall average unit OEM price for 3.5" floppy drives is forecasted to be only $9 in 2002.

The sales outlook for thin floppy drive models currently looks much better than for standard one inch high drives. Demand for 12.7 millimeter high floppy drives is driven mostly by the continuing expansion of the notebook computer market. Despite the tendency to eliminate the floppy drive in the smaller notebook computer implementations, a high percentage of the buyers of very thin notebook computers sold without floppy drives have purchased externally attached floppy drives. And because of the requirement to keep external floppy drive packages as small as possible, most of them use thin floppy drives. The current projections anticipate that shipments of drives less than one inch high during the 2000-2002 period will decline, but at a slower rate than for one inch high drives. Worldwide unit shipments of the thin drives are not expected to peak until 2002.

Technical trends

Several years ago, several floppy drive manufacturers undertook development programs to increase floppy drive capacities into the 2-5 megabyte range. Most of the programs resulted in producible products, but all failed in the marketplace due to limited industry support and high product prices. As attempts to upgrade the standard floppy disk drive configurations with increased capacity have failed, the product development target for all remaining manufacturers of low capacity floppy drives has become cost reduction. Intense activity has resulted in lower costs through reduction of electronic and mechanical parts counts, and through substitution of alternate materials.

The industry's failure to reduce costs fast enough for the 2.88 megabyte 3.5" drive prevented it from becoming a mainstream product. The biggest problem was the greater complexity and higher costs associated with the multifunction head required to provide downward compatibility with .7 and 1.44 megabyte drives. The result was 2.88 megabyte drives with selling prices twice those of standard 1.44 megabyte 3.5" floppy drives -- and a distinct lack of enthusiasm by most manufacturers of personal computers.

The next challenges for most manufacturers of 3.5" drives are packaging problems in reducing the height of the drive to meet the demand for half inch high drives -- and to hold down costs at the same time. It has been very expensive and technically difficult for most manufacturers to match competition with continually smaller drive configurations. Nevertheless, the changes have been achievable, once production of smaller motors and other key components became available. The floppy drive manufacturers' attempts to retain as much of a market as possible with manufacturers of notebook computers will provide a continuing incentive to reduce the production costs of floppy drives 12.7 millimeters or less in thickness to levels much closer to those of one inch high drives.

Forecasting assumptions

1. Shipments of one inch high 3.5" drives will decline after 2000, and overall shipments of drives with heights less that one inch will not peak until 2002.

2. 1999 will be the last year of production for 8" drives and 2000 will be the last production year for 5.25" floppy drives.

3. A positive growth rate for personal computers will continue through 2002.

TABLE 61

LOW-CAPACITY FLEXIBLE DISK DRIVES

REVENUE SUMMARY

	DISK DRIVE REVENUES, BY SHIPMENT DESTINATION ($M)									
	1998		Forecast							
	Revenues		1999		2000		2001		2002	
	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW
U.S. Manufacturers										
TOTAL U.S. REVENUES	--	--	--	--	--	--	--	--	--	--
Non-U.S. Manufacturers										
Captive	5.0	71.2	--	73.3	3.6	70.0	7.1	67.4	9.9	64.9
Distributor	219.6	534.8	188.0	451.0	164.9	399.9	162.8	394.8	141.1	341.6
OEM/Integrator	285.8	1,014.1	290.8	967.6	273.4	911.2	249.6	839.4	219.6	745.5
TOTAL NON-U.S. REVENUES	510.4	1,620.1	478.8	1,491.9	441.9	1,381.1	419.5	1,301.6	370.6	1,152.0
Worldwide Recap										
TOTAL WORLDWIDE REVENUES	510.4	1,620.1	478.8	1,491.9	441.9	1,381.1	419.5	1,301.6	370.6	1,152.0
OEM Average Price ($000)		.014		.012		.011		.010		.009

TABLE 62

LOW CAPACITY FLEXIBLE DISK DRIVES

UNIT SHIPMENT SUMMARY

	DISK DRIVE UNIT SHIPMENTS, BY SHIPMENT DESTINATION (000)									
	1998 Shipments		Forecast 1999		2000		2001		2002	
	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW	U.S.	WW
U.S. Manufacturers										
TOTAL U.S. SHIPMENTS	--	--	--	--	--	--	--	--	--	--
Non-U.S. Manufacturers										
Captive	120.0	1,495.0	--	1,720.0	80.0	1,775.0	170.0	1,840.0	255.0	1,915.0
Distributor	16,851.0	41,221.0	16,475.0	39,958.0	16,360.0	39,775.0	16,155.0	39,270.0	15,525.0	37,710.0
OEM/Integrator	21,176.0	70,705.0	25,209.0	78,554.0	25,696.0	80,839.0	25,875.0	81,610.0	25,350.0	80,100.0
TOTAL NON-U.S. SHIPMENTS	38,147.0	113,421.0	41,684.0	120,232.0	42,136.0	122,389.0	42,200.0	122,720.0	41,130.0	119,725.0
Worldwide Recap										
TOTAL WORLDWIDE SHIPMENTS	38,147.0	113,421.0	41,684.0	120,232.0	42,136.0	122,389.0	42,200.0	122,720.0	41,130.0	119,725.0
Cumulative Shipments (Units in millions)										
WORLDWIDE TOTAL	354.6	863.8	396.3	984.0	438.4	1,106.4	480.6	1,229.1	521.8	1,348.9

TABLE 63

LOW CAPACITY FLEXIBLE DISK DRIVES

WORLDWIDE REVENUES ($M)

BREAKDOWN BY DISK DIAMETER

	1998 Revenues			Forecast 1999			2000		2001	2002
	8"	5.25"	3.5"	8"	5.25"	3.5"	5.25"	3.5"	3.5"	3.5"
U.S. MANUFACTURERS										
TOTAL U.S. REVENUES	--	--	--	--	--	--	--	--	--	--
NON-U.S. MANUFACTURERS										
Captive	--	--	71.2	--	--	73.3	--	70.0	67.4	64.9
Distributor	--	.5	534.3	--	.1	450.9	--	399.9	394.8	341.6
OEM/Integrator	1.1	2.2	1,010.8	.9	1.5	965.2	.8	910.4	839.4	745.5
TOTAL NON-U.S. REVENUES	1.1	2.7	1,616.3	.9	1.6	1,489.4	.8	1,380.3	1,301.6	1,152.0
WORLDWIDE RECAP										
Captive	--	--	71.2	--	--	73.3	--	70.0	67.4	64.9
	--	--	-55.9%	--	--	+2.9%	--	-4.5%	-3.7%	-3.7%
Distributor	--	.5	534.3	--	.1	450.9	--	399.9	394.8	341.6
	--	-78.3%	+1.7%	--	-80.0%	-15.6%	--	-11.3%	-1.3%	-13.5%
OEM/Integrator	1.1	2.2	1,010.8	.9	1.5	965.2	.8	910.4	839.4	745.5
	+22.2%	-43.6%	--	-18.2%	-31.8%	-4.5%	-46.7%	-5.7%	-7.8%	-11.2%
Total Revenues	1.1	2.7	1,616.3	.9	1.6	1,489.4	.8	1,380.3	1,301.6	1,152.0
	+22.2%	-59.1%	-4.9%	-18.2%	-40.7%	-7.9%	-50.0%	-7.3%	-5.7%	-11.5%
ANNUAL SHARE, BY DIAMETER	.1%	.2%	99.7%	.1%	.1%	99.8%	.1%	99.9%	100.0%	100.0%

TABLE 64

LOW CAPACITY FLEXIBLE DISK DRIVES

WORLDWIDE SHIPMENTS (000)

BREAKDOWN BY DISK DIAMETER

	1998 Shipments			Forecast 1999			Forecast 2000		Forecast 2001	Forecast 2002
	8"	5.25"	3.5"	8"	5.25"	3.5"	5.25"	3.5"	3.5"	3.5"
U.S. MANUFACTURERS										
TOTAL U.S. SHIPMENTS	--	--	--	--	--	--	--	--	--	--
NON-U.S. MANUFACTURERS										
Captive	--	--	1,495.0	--	--	1,720.0	--	1,775.0	1,840.0	1,915.0
Distributor	--	18.0	41,203.0	--	5.0	39,953.0	--	39,775.0	39,270.0	37,710.0
OEM/Integrator	4.0	22.0	70,679.0	3.0	16.0	78,535.0	9.0	80,830.0	81,610.0	80,100.0
TOTAL NON-U.S. SHIPMENTS	4.0	40.0	113,377.0	3.0	21.0	120,208.0	9.0	122,380.0	122,720.0	119,725.0
WORLDWIDE RECAP										
Captive	--	--	1,495.0	--	--	1,720.0	--	1,775.0	1,840.0	1,915.0
	--	--	-53.2%	--	--	+15.1%	--	+3.2%	+3.7%	+4.1%
Distributor	--	18.0	41,203.0	--	5.0	39,953.0	--	39,775.0	39,270.0	37,710.0
	--	-77.5%	+17.7%	--	-72.2%	-3.0%	--	-.4%	-1.3%	-4.0%
OEM/Integrator	4.0	22.0	70,679.0	3.0	16.0	78,535.0	9.0	80,830.0	81,610.0	80,100.0
	--	-76.8%	+17.8%	-25.0%	-27.3%	+11.1%	-43.7%	+2.9%	+1.0%	-1.9%
Total Shipments	4.0	40.0	113,377.0	3.0	21.0	120,208.0	9.0	122,380.0	122,720.0	119,725.0
	--	-77.8%	+15.4%	-25.0%	-47.5%	+6.0%	-57.1%	+1.8%	+.3%	-2.4%
ANNUAL SHARE, BY DIAMETER	--	--	100.0%	--	--	100.0%	--	100.0%	100.0%	100.0%

TABLE 65

LOW CAPACITY FLEXIBLE DISK DRIVES

WORLDWIDE SHIPMENTS (000)

DRIVE HEIGHT ANALYSIS

	1998 --Shipments-- Units	%	Forecast -----1999---- Units	%	-----2000---- Units	%	-----2001---- Units	%	-----2002---- Units	%
U.S. MANUFACTURERS										
Total U.S.	--		--		--		--		--	
NON-U.S. MANUFACTURERS										
Captive Total	1,495.0		1,720.0		1,775.0		1,840.0		1,915.0	
Less than 1 inch	760.0	50.8%	950.0	55.2%	1,010.0	56.9%	1,085.0	59.0%	1,165.0	60.8%
1 inch	735.0	49.2%	770.0	44.8%	765.0	43.1%	755.0	41.0%	750.0	39.2%
Noncaptive Total	111,882.0		118,488.0		120,605.0		120,880.0		117,810.0	
Less than 1 inch	14,134.0	12.6%	16,058.0	13.6%	17,270.0	14.3%	17,785.0	14.7%	17,760.0	15.1%
1 inch	97,748.0	87.4%	102,430.0	86.4%	103,335.0	85.7%	103,095.0	85.3%	100,050.0	84.9%
Total Non-U.S.	113,377.0		120,208.0		122,380.0		122,720.0		119,725.0	
Less than 1 inch	14,894.0	13.1%	17,008.0	14.1%	18,280.0	14.9%	18,870.0	15.4%	18,925.0	15.8%
1 inch	98,483.0	86.9%	103,200.0	85.9%	104,100.0	85.1%	103,850.0	84.6%	100,800.0	84.2%
WORLDWIDE SHIPMENTS										
Total Worldwide Ship	113,377.0		120,208.0		122,380.0		122,720.0		119,725.0	
	+15.4%		+6.0%		+1.8%		+.3%		-2.3%	
Less than 1 inch	14,894.0	13.1%	17,008.0	14.1%	18,280.0	14.9%	18,870.0	15.4%	18,925.0	15.8%
	+17.6%		+14.2%		+7.5%		+3.2%		+.3%	
1 inch	98,483.0	86.9%	103,200.0	85.9%	104,100.0	85.1%	103,850.0	84.6%	100,800.0	84.2%
	+15.1%		+4.8%		+.9%		-.1%		-2.8%	

Notes: Percentage figures with plus/minus signs refer to year-to-year growth rates.

TABLE 66

LOW CAPACITY FLEXIBLE DISK DRIVES

APPLICATIONS SUMMARY
Percentage of Worldwide Shipments

APPLICATION	1998 Estimate Units (000)	1998 Estimate %	2002 Projection Units (000)	2002 Projection %
SPECIALIZED HIGH PERFORMANCE				
Supercomputers, video and high end imaging	90.7	.1	--	--
MAINFRAME SYSTEMS				
General purpose	--	--	--	--
NETWORK/MIDRANGE SYSTEMS				
Midrange systems, network servers and workstations	340.3	.3	--	--
DESKTOP PERSONAL COMPUTERS				
Business and professional, single user	71,489.3	63.0	71,475.8	59.7
CONSUMER COMPUTERS				
Desktop PCs, game, and hobby computers	25,735.2	22.7	29,093.2	24.3
PORTABLE COMPUTERS				
Notebook and smaller mobile computers	15,425.3	13.6	19,036.3	15.9
OTHER APPLICATIONS	294.8	.3	119.7	.1
Total	113,421.0	100.0	119,725.0	100.0

TABLE 67

LOW CAPACITY FLEXIBLE DISK DRIVES

MARKET SHARE SUMMARY
Worldwide Shipments of Noncaptive Disk Drives

	1998 Net Shipments									
	To United States Destinations					Worldwide				
	Units (000)				%	Units (000)				%
Drive Manufacturers	8"	5.25"	3.5"	Total		8"	5.25"	3.5"	Total	
Mitsumi Electric	--	--	7140.0	7140.0	18.8	--	--	21800.0	21800.0	19.5
Matsushita Comm. Ind.	--	--	6300.0	6300.0	16.6	--	--	18025.0	18025.0	16.1
TEAC	--	18.0	7820.0	7838.0	20.6	--	18.0	17180.0	17198.0	15.4
NEC	--	--	4650.0	4650.0	12.2	--	--	10510.0	10510.0	9.4
Samsung Electro-Mech.	--	--	3787.0	3787.0	10.0	--	--	10257.0	10257.0	9.2
Sony	--	--	3145.0	3145.0	8.3	--	--	9790.0	9790.0	8.7
Alps Electric	--	--	3070.0	3070.0	8.1	--	--	8280.0	8280.0	7.4
Mitsubishi	--	--	585.0	585.0	1.5	--	--	6875.0	6875.0	6.1
Citizen	--	--	450.0	450.0	1.2	--	--	5620.0	5620.0	5.0
Y-E Data	1.0	5.0	1056.0	1062.0	2.7	4.0	22.0	3525.0	3551.0	3.2
Other U.S.	--	--	--	--	--	--	--	--	--	--
Other Non-U.S.	--	--	--	--	--	--	--	20.0	20.0	--
TOTAL	1.0	23.0	38003.0	38027.0	100.0	4.0	40.0	111882.0	111926.0	100.0

CD FORMAT DISK DRIVE SPECIFICATIONS

CD FORMAT DISK DRIVE SPECIFICATIONS

Coverage: The following pages list CD format disk drives intended for computer data storage which are now announced or in new production. This includes CD-ROM, CD-R, CD-RW, DVD-ROM, DVD-R, and DVD-RAM. PD drives are included because they read CD-ROM media. In a few cases, products are listed for which only preliminary announcements have been made because they are judged to be significant indicators of industry direction in the production period shown.

Recording technology: The type of recording layer is indicated (magneto-optic, phase change, dye-polymer, etc.), except that the recording technology for CD-ROM is given as "Replication".

Drive type: Drive type is indicated as CD-ROM, CD-R, CD-RW, DVD-ROM, or PD as appropriate. Rewritable drives in this section use phase change technology unless otherwise indicated.

Relative speed: The data transfer rate relative to the original CD-ROM drives, which operated at "1X" speed, expressed as 4X, 8X, etc. The fastest rate is given. Most drives operate at several rates, falling back to a lower speed when reading poorly replicated disks or otherwise limited. For CAV drives, the range of effective relative speeds is given.

Interface: Specific interfaces are listed for most of the drives.

Speed control: The following abbreviations are used:

CAV = constant angular velocity.

CLV = constant linear velocity.

ZCAV = zoned constant angular velocity.

PCAV = partial constant angular velocity, a CAV/CLV hybrid.

Capacities: Capacities are listed as "U" for unformatted and "F" for formatted. For optical drives that can access only one side of the media, drives are categorized in terms of one side capacity, even if the drive uses two-sided media. As optical media is preformatted, the capacity given is the formatted capacity. Track capacity in CD format drives is variable, so this parameter will be "N/A" except in rare cases where drives have multiple operating modes. For CD-ROM drives, the capacity given is the nominal capacity unless otherwise stated.

Rotational speed: If more than one speed range exists, as for CD-ROM drives, only the highest performance range is given.

Servo type: All CD format drives use a continuous servo tracking scheme.

Average access time: The average access time is the sum of average positioning time plus rotational latency. Optical disk drive manufacturers, and especially CD-ROM manufacturers, are inconsistent in the use of this definition, so while the values given for these specifications are believed to be accurate, they should be accepted with caution and individual drive manufacturers contacted for details.

Data transfer rate: The data transfer rate given is the rate from the disk during reading. When more than one rate is given:

If separated by a hyphen, the figures represent the drive's minimum and maximum transfer rates.

If separated by a slash, the figures represent the rates obtained when the drive (such as the PD drive) operates in more than one mode or offers more than one capacity.

CD-ROM drives list the nominal data transfer rate for the operating mode (6X, 8X, 12X, etc.).

Accuracy: All of the information in this section has been checked for accuracy. Due to rapid changes in the industry, report users may need to make verbal inquiries of manufacturers for updates. Where data is not specified or otherwise unavailable, the abbreviation "NS" is used. Where a specification is not applicable, the abbreviation "N/A" appears.

1999 DISK/TREND Optical and Removable Disk Drive product groups

Group number	Drives included
CD format optical disk drives	
20:	CD format read-only optical disk drives.
21:	DVD format read-only optical disk drives.
22:	CD/DVD format writable optical disk drives.
Read/write optical disk drives	
23	Read/Write optical disk drives, less than 4 gigabytes.
24	Read/Write optical disk drives, more than 4 gigabytes.
Removable rigid disk drives	
1	Rigid disk cartridge drives.
2	Card format rigid disk drives.
Flexible disk drives	
13	High capacity flexible disk drives.
14	Low capacity flexible disk drives.

MANUFACTURER	ACER PERIPHERALS	ACER PERIPHERALS	ACER PERIPHERALS	ACER PERIPHERALS	ACER PERIPHERALS
CD FORMAT DRIVE	CD-640P	CD-648A	CD-650P	CD-840A	DV-605A
DISK/TREND GROUP	20	20	20	20	21
MARKET	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST
MEDIA: Recording technology	Replication	Replication	Replication	Replication	Replication
DRIVE: Drive type	CD-ROM	CD-ROM	CD-ROM	CD-ROM	DVD-ROM
Relative speed: Read	40X max.	48X max.	50X max.	40X	4.8X/36.5X*
Relative speed: Write	--	--	--	--	--
Rotational speed (RPM)					
Interface	IDE/ATAPI	IDE/ATAPI	IDE/ATAPI	IDE/ATAPI	IDE/ATAPI
Disk insertion	Tray	Tray	Tray	Tray	Tray
Speed control	CAV	CAV	CAV	CAV	CAV
CAPACITY/RECORDING DENSITY					
Nominal capacity (Gigabytes)	F: .65	F: .65	F: .65	F: .65	F: .65*/4.7/8.5
Data surfaces per spindle	1	1	1	1	1, 2
Track density (TPI)	15875	15875	15875	15875	34324
Maximum linear density (BPI)	27600	27600	27600	27600	96000
PERFORMANCE					
Buffer/cache size (KBytes)	128	128	128	128	128
Average positioning time (msec)					
Average access time (msec)	100	100	85	85	135/90*
Data transfer rate (MBytes/sec) Internal	6.0 max.	7.2 max.	7.5 max.	6.0 max.	6.536/5.475*
External	33.3 Ultra DMA	33.3 Ultra DMA	33.3 Ultra DMA		33.3 Ultra DMA
SIZE (mm: H x W x D)	42 x 146 x 198	42 x 146 x 198	42 x 146 x 198	42 x 146 x 198	42 x 146 x 201
FIRST CUSTOMER SHIPMENT				3Q98	
COMMENTS					*CD-ROM mode.

MANUFACTURER	ACER PERIPHERALS	ACER PERIPHERALS	ACER PERIPHERALS	ACTIMA	ACTIMA
CD FORMAT DRIVE	DVD-606A	CRW-4432A	CRW-6206A	A44T	A50T
DISK/TREND GROUP	21	22	22	20	20
MARKET	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST
MEDIA: Recording technology	Replication	Phase Change	Phase Change	Replication	Replication
DRIVE: Drive type	DVD-ROM	CD-RW	CD-RW	CD-ROM	CD-ROM
Relative speed: Read	6X/32X*	32X	6X	44X max.	50X max.
Relative speed: Write	--	4X	2X	--	--
Rotational speed (RPM)			3180-400	8800	10000
Interface	IDE/ATAPI	IDE/ATAPI	IDE/ATAPI	IDE/ATAPI	IDE/ATAPI
Disk insertion	Tray	Tray	Tray	Tray	Tray
Speed control	CAV	CLV/CAV	CLV	CAV	CAV
CAPACITY/RECORDING DENSITY					
Nominal capacity (Gigabytes)	F: .65/4.7/8.5	F: .65	F: .65	F: .65	F: .65
Data surfaces per spindle	1, 2	1	1	1	1
Track density (TPI)	34324	15875	15875	15875	15875
Maximum linear density (BPI)	96000	27600	27600	27600	27600
PERFORMANCE					
Buffer/cache size (KBytes)		1000	512	128	128
Average positioning time (msec)	105				
Average access time (msec)	135/95*	120	300	100	95
Data transfer rate (MBytes/sec) Internal	8.1/4.8*	.6/4.8	.6 WR/.9 RD	6.6 max.	7.5 max.
External		33.3 Ultra DMA		16.7, 33 UDMA	16.7, 33 UDMA
SIZE (mm: H x W x D)		42 x 146 x 198	42 x 146 x 210	42 x 146 x 197	42 x 146 x 197
FIRST CUSTOMER SHIPMENT	7/99			4Q98	2Q99
COMMENTS	*CD-ROM mode.				

MANUFACTURER	ACTIMA	ACTIMA	AFREEY	AFREEY	AFREEY
CD FORMAT DRIVE	AD05P	ARW4420	CD-184DE 40X	CD-184SE 45X	CD-2250E 50X
DISK/TREND GROUP	21	22	20	20	20
MARKET	OEM, DIST	OEM, DIST	DIST, OEM	DIST, OEM	DIST, OEM
MEDIA: Recording technology	Replication	Phase Change	Replication	Replication	Replication
DRIVE: Drive type	DVD-ROM	CD-RW	CD-ROM	CD-ROM	CD-ROM
Relative speed: Read	6X/32X*	20X	40X	45X	50X
Relative speed: Write	--	4X	--	--	--
Rotational speed (RPM)					
Interface	IDE/ATAPI	IDE/ATAPI	IDE/ATAPI	IDE/ATAPI	IDE/ATAPI
Disk insertion	Slot	Tray	Tray	Tray	Tray
Speed control	CAV	CAV	CAV	CAV	CAV
CAPACITY/RECORDING DENSITY					
Nominal capacity (Gigabytes)	F: 4.7/8.5	F: .65	F: .65	F: .65	F: .65
Data surfaces per spindle	1, 2	1	1	1	1
Track density (TPI)	34324	15875	15875	15875	15875
Maximum linear density (BPI)	96000	27600	27600	27600	27600
PERFORMANCE					
Buffer/cache size (KBytes)	500	2000	128	128	128
Average positioning time (msec)			80	80	80
Average access time (msec)	120/90*	120			
Data transfer rate (MBytes/sec) Internal	8.1/4.8*	3.0/.6	2.7-6.0	2.7-6.75	2.7-7.5
External	16.7, 33 UDMA	16.7 PIO Mode 4	33 Ultra DMA	33 Ultra DMA	33 Ultra DMA
SIZE (mm: H x W x D)	42.3 x 148 x 207.5	41.3 x 146 x 203	42 x 149 x 196.5	42 x 149 x 196.5	42 x 149 x 196.5
FIRST CUSTOMER SHIPMENT	4Q98	4Q98	9/98	4Q98	4Q98
COMMENTS	*CD-ROM mode.				

MANUFACTURER	AFREEY	AFREEY	AFREEY	AOPEN	AOPEN
CD FORMAT DRIVE	CD-2255E 55X	DD-3205 5X	DD-3206 6X	CD-940E	CD-948E
DISK/TREND GROUP	20	21	21	20	20
MARKET	DIST, OEM	DIST, OEM	DIST, OEM	OEM, DIST	OEM, DIST
MEDIA: Recording technology	Replication	Replication	Replication	Replication	Replication
DRIVE: Drive type	CD-ROM	DVD-ROM	DVD-ROM	CD-ROM	CD-ROM
Relative speed: Read	55X	5X/32X* max.	6X/32X* max.	40X	22X-48X
Relative speed: Write	--	--	--	--	--
Rotational speed (RPM)				8700	9700
Interface	IDE/ATAPI	IDE/ATAPI	IDE/ATAPI	IDE/ATAPI	IDE/ATAPI
Disk insertion	Tray	Tray	Tray	Tray	Tray
Speed control	CAV	CAV	CAV	CAV	CAV
CAPACITY/RECORDING DENSITY					
Nominal capacity (Gigabytes)	F: .65	F: 4.7/8.5	F: 4.7/8.5	.782 Mode 2 F: .656 Mode 1	F: .65
Data surfaces per spindle	1	1, 2	1, 2	1	1
Track density (TPI)	15875	34324	34324	15875	15875
Maximum linear density (BPI)	27600	96000	96000	27600	27600
PERFORMANCE					
Buffer/cache size (KBytes)	128			128	512
Average positioning time (msec)	80				
Average access time (msec)		110/90*	110/90*	85	85
Data transfer rate (MBytes/sec) Internal		6.75/4.8*	6.75/4.8*	2.4-6.0	3.3-7.2
External	33 Ultra DMA	33 Ultra DMA	33 Ultra DMA		33.3 Ultra DMA
SIZE (mm: H x W x D)	42 x 149 x 196.5	42 x 149 x 196.5	42 x 149 x 196.5	42 x 149 x 196.5	41.3 x 149 x 196.6
FIRST CUSTOMER SHIPMENT	6/99	4/99	6/99	3Q98	4Q98
COMMENTS		*CD-ROM mode.	*CD-ROM mode.		MultiRead.

MANUFACTURER	AOPEN	AOPEN	AOPEN	AOPEN	AOPEN
CD FORMAT DRIVE	CD-956E	DVD-9432	DVD-9624	DVD-9632	DVD-9836
DISK/TREND GROUP	20	21	21	21	21
MARKET	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST
MEDIA: Recording technology	Replication	Replication	Replication	Replication	Replication
DRIVE: Drive type	CD-ROM	DVD-ROM	DVD-ROM	DVD-ROM	DVD-ROM
Relative speed: Read	56X	4X/32X*	6X/24X*	6X/32X*	8X/36X*
Relative speed: Write		--	--	--	
Rotational speed (RPM)	11500	--			
Interface	IDE	IDE/ATAPI	IDE/ATAPI	IDE/ATAPI	IDE
Disk insertion	Tray	Tray	Tray	Slot	Tray
Speed control	CAV	CLV	CAV	CAV	CAV
CAPACITY/RECORDING DENSITY					
Nominal capacity (Gigabytes)	F: .65	8.5 F: 4.7	F: 4.7/8.5	F: 4.7/8.5	F: 4.7/8.5
Data surfaces per spindle	1	1, 2	1, 2	1, 2	1, 2
Track density (TPI)	15875	34324	34324	34324	34324
Maximum linear density (BPI)	27600	96000	96000	96000	96000
PERFORMANCE					
Buffer/cache size (KBytes)	128		512	512	512
Average positioning time (msec)					
Average access time (msec)	85			120/90*	85
Data transfer rate (MBytes/sec) Internal External	8.4 max.	5.52/4.8*	8.3/3.6*	8.31/4.8* 33.3 Ultra DMA	11.8
SIZE (mm: H x W x D)	42 x 149 x 196.5	41.3 x 146 x 196			42 x 149 x 196.5
FIRST CUSTOMER SHIPMENT	4Q99	4Q98			4Q99
COMMENTS	MultiRead.	*CD-ROM mode.	*CD-ROM mode. MultiRead.	*CD-ROM mode.	*CD-ROM mode.

MANUFACTURER	AOPEN	AOPEN	AOPEN	AOPEN	AOPEN
CD FORMAT DRIVE	CRS-9420	CRW-9420	CRW-9420S	CRW-9624	DVD-520S
DISK/TREND GROUP	22	22	22	22	22
MARKET	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST	DIST
MEDIA: Recording technology	Phase Change	Phase Change	Phase Change	Phase Change	Phase Change
DRIVE: Drive type	CD-RW	CD-RW	CD-RW	CD-RW	DVD-RAM
Relative speed: Read	20X	20X	20X	24X	2X/20X
Relative speed: Write	4X	4X	4X	6X	1X
Rotational speed (RPM)		--			--
Interface	PCMCIA, USB	IDE/ATAPI	SCSI	IDE	SCSI-2
Disk insertion	Tray	Tray	Tray	Tray	Caddy
Speed control	CLV	CLV	CLV	CLV	CLV
CAPACITY/RECORDING DENSITY					
Nominal capacity (Gigabytes)	F: .65	.782 Mode 2 F: .656 Mode 1	F: .65	F: .65	F: 2.6/5.2
Data surfaces per spindle	1	1	1	1	1, 2
Track density (TPI)	15875	15875	15875	15875	34324
Maximum linear density (BPI)	27600	27600	27600	27600	62000
PERFORMANCE					
Buffer/cache size (KBytes)	2048	2048	2048	2048	2048
Average positioning time (msec)					
Average access time (msec)					85/120
Data transfer rate (MBytes/sec) Internal External	.6/3.0	.6/3.6	.6/3.0	.9/3.6	10
SIZE (mm: H x W x D)	12.7 x 128.7 x 142	41.3 x 146 x 203	42 x 149 x 196.5	42 x 149 x 196.5	41.3 x 146 x 196
FIRST CUSTOMER SHIPMENT	3Q99	4Q98	3Q99	3Q99	3Q98
COMMENTS	Ricoh mechanism.	Ricoh mechanism.	Ricoh mechanism.	Ricoh mechanism.	Panasonic mechanism.

MANUFACTURER	ASUSTEK COMPUTER	ASUSTEK COMPUTER	ASUSTEK COMPUTER	BEHAVIOR TECH COMPUTER	BEHAVIOR TECH COMPUTER
CD FORMAT DRIVE	CD-S400	CD-S450	CD-S500	BCD 40SB	BCD 40XH
DISK/TREND GROUP	20	20	20	20	20
MARKET	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST
MEDIA: Recording technology	Replication	Replication	Replication	Replication	Replication
DRIVE: Drive type	CD-ROM	CD-ROM	CD-ROM	CD-ROM	CD-ROM
Relative speed: Read	40X max.	40X max.	40X max.	40X max.	40X max.
Relative speed: Write	--	--	--	--	--
Rotational speed (RPM)	8900	9300	10400		8500-200
Interface	IDE/ATAPI	IDE/ATAPI	IDE/ATAPI	IDE/ATAPI	IDE/ATAPI
Disk insertion	Tray	Tray	Tray	Tray	Tray
Speed control	CAV	CAV	CAV	CAV	CAV
CAPACITY/RECORDING DENSITY					
Nominal capacity (Gigabytes)	F: .650	F: .650	F: .650	F: .65	F: .650
Data surfaces per spindle	1	1	1	1	1
Track density (TPI)	15875	15875	15875	15875	15875
Maximum linear density (BPI)	27600	27600	27600	27600	27600
PERFORMANCE					
Buffer/cache size (KBytes)	128	128	128	128	256
Average positioning time (msec)	75	75	75		
Average access time (msec)				80	100
Data transfer rate (MBytes/sec) Internal	2.8-6.0	3.0-6.75	3.3-7.5	6.0	6.0
External		33 Ultra DMA	33 Ultra DMA		16.6 PIO Mode 4
SIZE (mm: H x W x D)	41.5 x 149 x 197	41.5 x 149 x 197	41.5 x 149 x 197	41.4 x 145.8 x 200	42 x 149 x 202
FIRST CUSTOMER SHIPMENT	3Q98	4Q98	2Q99		3Q98
COMMENTS					

MANUFACTURER	BEHAVIOR TECH COMPUTER	BEHAVIOR TECH COMPUTER	BEHAVIOR TECH COMPUTER	BEHAVIOR TECH COMPUTER	BEHAVIOR TECH COMPUTER
CD FORMAT DRIVE	BCD 48SB	BDV 840HS	BCE 2421E	BCE 4241	BCE 4424
DISK/TREND GROUP	20	21	22	22	22
MARKET	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST
MEDIA: Recording technology	Replication	Replication	Phase Change	Phase Change	Dye Polymer
DRIVE: Drive type	CD-ROM	DVD-ROM	CD-RW	CD-RW	CD-R
Relative speed: Read	48X max.	8X/40X*	24X max.	24X	24X
Relative speed: Write	--	--	2X	4X	4X
Rotational speed (RPM)					
Interface	IDE/ATAPI	IDE/ATAPI	IDE/ATAPI	IDE/ATAPI	IDE/ATAPI
Disk insertion	Tray	Tray	Tray	Tray	Tray
Speed control	CAV	CLV	CAV/CLV	CLV	CLV
CAPACITY/RECORDING DENSITY					
Nominal capacity (Gigabytes)	F: .65	F: 4.7/8.5	F: .65	F: .650	F: .65
Data surfaces per spindle	1	1, 2	1	1	1
Track density (TPI)	15875	34324	15875	15875	15875
Maximum linear density (BPI)	27600	96000	27600	27600	27600
PERFORMANCE					
Buffer/cache size (KBytes)	128		1000	2000	1000
Average positioning time (msec)					
Average access time (msec)	80	100/80*	100	120	
Data transfer rate (MBytes/sec) Internal / External	7.2	11.8/6.0* 33.4 Ultra DMA	3.6/.3	.6/3.6	.6/3.6
SIZE (mm: H x W x D)	41.4 x 145.8 x 200	40.7 x 146 x 187.5	42 x 149 x 200	42 x 148.5 x 201	42 x 149 x 210.5
FIRST CUSTOMER SHIPMENT		4Q99		3Q99	1999
COMMENTS		*CD-ROM mode.			

MANUFACTURER	BEHAVIOR TECH COMPUTER	DELTA ELECTRONICS	DELTA ELECTRONICS	DELTA ELECTRONICS	DELTA ELECTRONICS
CD FORMAT DRIVE	BCE 621E BCE 62PE	OIP-CD4400A	OIP-CD4800A	ODE-6121	OME-W141
DISK/TREND GROUP	22	20	20	22	22
MARKET	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST	DIST
MEDIA: Recording technology	Phase Change	Replication	Replication	Phase Change	Phase Change
DRIVE: Drive type	CD-RW	CD-ROM	CD-ROM	CD-RW	CD-RW
Relative speed: Read	6X	44X	48X	6X	20X
Relative speed: Write	2X	--	--	2X	4X
Rotational speed (RPM)					
Interface	IDE/ATAPI	IDE/ATAPI	IDE/ATAPI	IDE/ATAPI	IDE/ATAPI
Disk insertion	Tray	Tray	Tray	Tray	Tray
Speed control	CLV	CAV	CAV	CLV	CAV/CLV
CAPACITY/RECORDING DENSITY					
Nominal capacity (Gigabytes)	F: .650	F: .65	F: .65	.740 Mode 2 F: .650 Mode 1	F: .65
Data surfaces per spindle	1	1	1	1	1
Track density (TPI)	15875	15875	15875	15875	15875
Maximum linear density (BPI)	27600	27600	27600	27600	27600
PERFORMANCE					
Buffer/cache size (KBytes)	1000	128	128	1000	2000
Average positioning time (msec)		85	85		120
Average access time (msec)	350			320	
Data transfer rate (MBytes/sec) Internal External	.3/.9	6.6 max.	7.2 max.	.3 WR/.9 RD	.6/3.0
SIZE (mm: H x W x D)	42 x 149 x 213	41.5 x 146 x 201	41.5 x 146 x 201	41 x 146 x 203	41.3 x 146 x 203
FIRST CUSTOMER SHIPMENT	1997	2Q99	3Q99	1998	2Q99
COMMENTS	BCE 62PE is external mount with parallel port.				Purchased mechanism.

MANUFACTURER	DIGITAL VIDEO SYSTEMS	DIGITAL VIDEO SYSTEMS	EPO	EPO	EPO
CD FORMAT DRIVE	DSR-520H	DSR-600H	CR-836S	CR-840S	CR-848S
DISK/TREND GROUP	21	21	20	20	20
MARKET	OEM, DIST	OEM, DIST	DIST	DIST	DIST
MEDIA: Recording technology	Replication	Replication	Replication	Replication	Replication
DRIVE: Drive type	DVD-ROM	DVD-ROM	CD-ROM	CD-ROM	CD-ROM
Relative speed: Read	5.2X/32X*	6.2X/32X*	36X max.	40X max.	48X max.
Relative speed: Write	--	--	--	--	--
Rotational speed (RPM)					
Interface	IDE/ATAPI	IDE/ATAPI	IDE/ATAPI	IDE/ATAPI	IDE/ATAPI
Disk insertion	Tray	Tray	Tray	Tray	Tray
Speed control	CAV	CAV	CAV	CAV	CAV
CAPACITY/RECORDING DENSITY					
Nominal capacity (Gigabytes)	F: 4.7	F: 4.7	F: .65	F: .65	F: .65
Data surfaces per spindle	1, 2	1, 2	1	1	1
Track density (TPI)	34324	34324	15875	15875	15875
Maximum linear density (BPI)	96000	96000	27600	27600	27600
PERFORMANCE					
Buffer/cache size (KBytes)	512	512	128	128	128
Average positioning time (msec)			80	75	75
Average access time (msec)	120/90*	110/90*	90	85	85
Data transfer rate (MBytes/sec) Internal	7.2/4.8*	8.5/4.8	2.35-5.4	2.65-6.0	3.15-7.2
External	16.7 PIO Mode 4	16.7 PIO Mode 4			
SIZE (mm: H x W x D)	41.5 x 146 x 195	41.5 x 146 x 195	41.5 x 146 x 192	41.5 x 146 x 192	41.5 x 146 x 192
FIRST CUSTOMER SHIPMENT	5/98	2/99			
COMMENTS	*CD-ROM mode.	*CD-ROM mode.			

MANUFACTURER	HEWLETT-PACKARD	HEWLETT-PACKARD	HEWLETT-PACKARD	HEWLETT-PACKARD	HEWLETT-PACKARD
CD FORMAT DRIVE	3100i	C4380A 7200e 7200i CD-Writer Plus	C4392 8100i 8110i CD-Writer Plus	C4410A 9550i C4411A 7570i CD-Writer Plus	C4412A 7550e C4413A 7570e CD-Writer Plus
DISK/TREND GROUP	22	22	22	22	22
MARKET	DIST	CAPT,OEM,DIST	CAPT,OEM,DIST	CAPT,OEM,DIST	CAPT,OEM,DIST
MEDIA: Recording technology	Phase Change	Phase Change	Phase Change	Phase Change	Phase Change
DRIVE: Drive type	DVD+RW	CD-R, CD-RW	CD-R, CD-RW	CD-R, CD-RW	CD-R, CD-RW
Relative speed: Read	1X-2.5X/24X*	6X	24X	24X	24X
Relative speed: Write	1.25X	2X	4X/2X	2X/2X	2X/2X
Rotational speed (RPM)		3180-400			
Interface	SCSI-2	SCSI-2	IDE/ATAPI	IDE/ATAPI	Parallel Port
Disk insertion	Tray	Tray	Tray	Tray	Tray
Speed control	CAV	CLV	CLV/CAV	CLV/CAV	CLV/CAV
CAPACITY/RECORDING DENSITY Nominal capacity (Gigabytes)	F: 3.0	.682 F: .581	.682 F: .581	.682 F: .581	.682 F: .581
Data surfaces per spindle	1	1	1	1	1
Track density (TPI)		15875	15875	15875	15875
Maximum linear density (BPI)		27600	27600	27600	27600
PERFORMANCE Buffer/cache size (KBytes)		1000	1000	1000	1000
Average positioning time (msec)		290	125/150	125/150	125/150
Average access time (msec)		345 WR/310 RD			
Data transfer rate (MBytes/sec) Internal External	1.7/3.5/3.6*	.30 WR/.900 RD	.6/.3 WR,3.6 RD	.3/.3 WR,3.6 RD	.3/.3 WR,3.6 RD
SIZE (mm: H x W x D)		41.5 x 146 x 206	41.5 x 146 x 206	41.5 x 146 x 206	41.5 x 146 x 206
FIRST CUSTOMER SHIPMENT	2Q99	1Q98	3Q98	1999	5/99
COMMENTS	*CD-ROM mode.	7210e is external mount.			

MANUFACTURER	HEWLETT-PACKARD	HEWLETT-PACKARD	HITACHI	HITACHI	HITACHI
CD FORMAT DRIVE	C4414A 8200i C4415A 8210i CD-Writer Plus	C4450A M820e	CDR-8430	GD-2500	GD-3000
DISK/TREND GROUP	22	22	20	21	21
MARKET	CAPT,OEM,DIST	DIST	OEM, DIST	OEM, DIST	OEM, DIST
MEDIA: Recording technology	Phase Change	Phase Change	Replication	Replication	Replication
DRIVE: Drive type	CD-R, CD-RW	CD-RW	CD-ROM	DVD-ROM	DVD-ROM
Relative speed: Read	24X	20X	14X-32X		5X/
Relative speed: Write	4X/4X	4X(CD-R)/2X	--	--	--
Rotational speed (RPM)			7490	2304-3060	
Interface	IDE/ATAPI	PCMCIA/SCSI	IDE/ATAPI	IDE/ATAPI	IDE/ATAPI
Disk insertion	Tray	Top Loading	Tray	Tray	Tray
Speed control	CLV/CAV	CLV/CAV	CAV	CLV/CAV	CAV*/CLV
CAPACITY/RECORDING DENSITY					
Nominal capacity (Gigabytes)	.682 F: .581	F: .65	F: .65	F: 4.7/8.5	8.5 F: 4.7
Data surfaces per spindle	1	1	1	1, 2	1, 2
Track density (TPI)	15875	15875	15875	34324	34324
Maximum linear density (BPI)	27600	27600	27600	96000	96000
PERFORMANCE					
Buffer/cache size (KBytes)	2000	2000	128	512	512/256*
Average positioning time (msec)	125/150	150			
Average access time (msec)			80	180/120*	
Data transfer rate (MBytes/sec) Internal	.6/.6 WR,3.6 RD	.3/.6/3.0	2.1-4.8	2.76-5.52/3.6*	6.9
External			16.6 PIO Mode 4	16.6 PIO Mode 4	16.6 PIO Mode 4
SIZE (mm: H x W x D)	41.5 x 146 x 206	25 x 123 x 165	41.3 x 146 x 190	41.3 x 146 x 190	41.3 x 146 x 190
FIRST CUSTOMER SHIPMENT	1999	2Q99	4Q97	4Q98	1Q99
COMMENTS	8210 requires sound card for multimedia use.			*CD-ROM mode.	DVD-RAM compatible. *CD-ROM mode.

MANUFACTURER	HITACHI	HITACHI	HITACHI	JVC	JVC
CD FORMAT DRIVE	GF-1000	GF-1050	GF-1055	XR-W2080 XR-W2082 XR-RW2224	XR-W4080 XR-W4082 XR-RW4224
DISK/TREND GROUP	22	22	22	22	22
MARKET	OEM, DIST	OEM, DIST	OEM, DIST	DIST, OEM	DIST, OEM
MEDIA: Recording technology	Phase Change	Phase Change	Phase Change	Phase Change	Phase Change
DRIVE: Drive type	DVD-RAM	DVD-RAM	DVD-RAM	CD-RW	CD-RW
Relative speed: Read	2X*/8X**	2X*/8X**	2X*/8X**	24X	24X max.
Relative speed: Write	1X	1X	1X	2X R/2X RW	4X R/2X RW
Rotational speed (RPM)	1536-582	1536-582	1536-582		
Interface	IDE/ATAPI	SCSI-2	SCSI-2	IDE/ATAPI	IDE/ATAPI
Disk insertion	Tray	Tray	Tray	Tray	Tray
Speed control	ZCAV	ZCAV	ZCAV	CAV/CLV	CAV/CLV
CAPACITY/RECORDING DENSITY					
Nominal capacity (Gigabytes)	F:2.6/4.7*/8.8*	F:2.6/4.7*/8.8*	F:2.6/4.7*/8.8*	F: .65	F: .65
Data surfaces per spindle	1/2*	1/2*	1/2*	1	1
Track density (TPI)	34324	34324	34324	15875	15875
Maximum linear density (BPI)	62000	62000	62000	27600	27600
PERFORMANCE					
Buffer/cache size (KBytes)	1000	1000	1000	2000	2000
Average positioning time (msec)					
Average access time (msec)	210/150**	210/150**	210/150**	140 (RD)	140 (RD)
Data transfer rate (MBytes/sec) Internal External	1.38/2.76* 16.6 PIO Mode 4	1.38/2.76* 5.0/10.0 synch.	1.38/2.76* 5.0/10.0 synch.	3.6/.3	3.6/.6/.3
SIZE (mm: H x W x D)	41.3 x 146 x 208	41.3 x 146 x 208	50 x 180 x 343	43 x 149 x 208	43 x 149 x 208
FIRST CUSTOMER SHIPMENT	3Q98	3Q98	4/98	3Q98	1Q99
COMMENTS	*DVD-ROM mode. **CD-ROM mode. Dual laser pickup.	*DVD-ROM mode. **CD-ROM mode. Dual laser pickup.	*DVD-ROM mode. **CD-ROM mode. External mount. Dual laser pickup.		

MANUFACTURER	JVC	KENWOOD	KENWOOD	LEOPTICS	LEOPTICS
CD FORMAT DRIVE	XR-W4424	MULTI-BEAM 40X Plus	UCR-412 52X TrueX	CDD-1400	CDD-1450
DISK/TREND GROUP	22	20	20	20	20
MARKET	DIST, OEM	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST
MEDIA: Recording technology	Phase Change	Replication	Replication	Replication	Replication
DRIVE: Drive type	CD-RW	CD-ROM	CD-ROM	CD-ROM	CD-ROM
Relative speed: Read	24X	40X	45X-52X	40X max.	45X max.
Relative speed: Write	4X/4X	--	--	--	--
Rotational speed (RPM)		4500-1800	4750-1900		
Interface	IDE/ATAPI	IDE/ATAPI	IDE/ATAPI	IDE/ATAPI	IDE/ATAPI
Disk insertion	Tray	Tray	Tray	Tray	Tray
Speed control	CAV/CLV	CLV	CLV	CAV	CAV
CAPACITY/RECORDING DENSITY					
Nominal capacity (Gigabytes)	F: .65	F: .65	F: .65	F: .65	F: .65
Data surfaces per spindle	1	1	1	1	1
Track density (TPI)	15875	15875	27600	15875	15875
Maximum linear density (BPI)	27600	27600	15875	27600	27600
PERFORMANCE					
Buffer/cache size (KBytes)	2000	2000	2048	128	128
Average positioning time (msec)		70		80	80
Average access time (msec)	140 (RD)	85	90		
Data transfer rate (MBytes/sec) Internal External	3.6/.6/.6	6.0	6.75-7.8	6.0 max.	6.75 max.
SIZE (mm: H x W x D)	43 x 149 x 208	43 x 149 x 200	43 x 149 x 200		
FIRST CUSTOMER SHIPMENT	3Q99	3Q98	1Q99	1998	1999
COMMENTS		Zen Research 7 track parallel read head.			

MANUFACTURER	LEOPTICS	LEOPTICS	LEOPTICS	LG ELECTRONICS	LG ELECTRONICS
CD FORMAT DRIVE	CDD-1500	CDD-6060	CDD-3244	CRD-8241B	CRN-8241B
DISK/TREND GROUP	20	21	22	20	20
MARKET	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST	OEM, Captive
MEDIA: Recording technology	Replication	Replication	Phase Change	Replication	Replication
DRIVE: Drive type	CD-ROM	DVD-ROM	CD-RW	CD-ROM	CD-ROM
Relative speed: Read	50X max.	6X max.	24X max.	24X	24X
Relative speed: Write	--	--	4X	--	--
Rotational speed (RPM)				5230	5230
Interface	IDE/ATAPI	IDE/ATAPI	IDE/ATAPI	IDE/ATAPI	IDE/ATAPI
Disk insertion	Tray	Tray	Tray	Slot	Tray
Speed control	CAV	CAV	CAV/CLV	CAV	CAV
CAPACITY/RECORDING DENSITY Nominal capacity (Gigabytes)	F: .65	F: 4.7/8.5	F: .65	F: .65	F: .65
Data surfaces per spindle	1	1, 2	1	1	1
Track density (TPI)	15875	34324	15875	15875	15875
Maximum linear density (BPI)	27600	96000	27600	27600	27600
PERFORMANCE Buffer/cache size (KBytes)	128	128	2000	128	128
Average positioning time (msec)	80	90	120	90	100
Average access time (msec)					110
Data transfer rate (MBytes/sec) Internal External	7.5 max.	8.3 max.	.6/3.6 max.	3.6 max.	3.6 max.
SIZE (mm: H x W x D)		42 x 149 x 196.5	42 x 148 x 210	41.5 x 146 x 201	12.7 x 128 x 129
FIRST CUSTOMER SHIPMENT	1999	4Q99	3Q99	8/97	8/98
COMMENTS					MultiRead.

MANUFACTURER	LG ELECTRONICS	LG ELECTRONICS	LG ELECTRONICS	LG ELECTRONICS	LG ELECTRONICS
CD FORMAT DRIVE	CRD-8320B	CRD-8322B	CRD-8360B	CRD-8400C	CRD-8480B
DISK/TREND GROUP	20	20	20	20	20
MARKET	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST
MEDIA: Recording technology	Replication	Replication	Replication	Replication	Replication
DRIVE: Drive type	CD-ROM	CD-ROM	CD-ROM	CD-ROM	CD-ROM
Relative speed: Read	32X max.	32X max.	36X	40X	48X
Relative speed: Write	--	--	--	--	--
Rotational speed (RPM)	6420	6420			
Interface	IDE/ATAPI	IDE/ATAPI	IDE/ATAPI	IDE/ATAPI	IDE/ATAPI
Disk insertion	Tray	Tray	Tray	Tray	Tray
Speed control	CAV	CAV	CAV	CAV	CAV
CAPACITY/RECORDING DENSITY					
Nominal capacity (Gigabytes)	F: .65	F: .65	F: .65	F: .65	F: .65
Data surfaces per spindle	1	1	1	1	1
Track density (TPI)	15875	15875	15875	15875	15875
Maximum linear density (BPI)	27600	27600	27600	27600	27600
PERFORMANCE					
Buffer/cache size (KBytes)	128	128	128	128	128
Average positioning time (msec)	80				
Average access time (msec)	90	80	75	75	75
Data transfer rate (MBytes/sec) Internal	4.8 max.	4.8 max.	5.4 max.	6.0 max.	7.2 max.
External		16.7 PIO Mode 4	33 Ultra DMA	33 Ultra DMA	33.3 Ultra DMA
SIZE (mm: H x W x D)	41.4 x 146 x 201	42 x 149 x 208	41.5 x 146 x 201	41.5 x 146 x 201	41.5 x 146 x 201
FIRST CUSTOMER SHIPMENT	11/97	6/98	11/98	12/98	1Q99
COMMENTS	MultiRead.		MultiRead.	MultiRead.	MultiRead.

MANUFACTURER	LG ELECTRONICS	LG ELECTRONICS	LG ELECTRONICS	LG ELECTRONICS	LG ELECTRONICS
CD FORMAT DRIVE	CRN-8240E	DRD-8060B	DRD-8080B	DRD-840B	DRD-841B
DISK/TREND GROUP	20	21	21	21	21
MARKET	DIST	OEM, DIST	OEM, DIST	OEM,DIST,CAPT	OEM, DIST
MEDIA: Recording technology	Replication	Replication	Replication	Replication	Replication
DRIVE: Drive type	CD-ROM	DVD-ROM	DVD-ROM	DVD-ROM	DVD-ROM
Relative speed: Read	12X/7X**	6X/32X*	8X/36X*	4X/32X*	4X/32X*
Relative speed: Write	--	--	--	--	
Rotational speed (RPM)					
Interface	IDE/ATAPI*	IDE/ATAPI	IDE/ATAPI	IDE/ATAPI	IDE/ATAPI
Disk insertion	Tray	Tray	Tray	Tray	Tray
Speed control	CAV	CAV	CAV	CLV/CAV	CAV
CAPACITY/RECORDING DENSITY					
Nominal capacity (Gigabytes)	F: .65	F: 4.7/8.5	F: 4.7/8.5	F: 4.7/8.5	F: 4.7/8.5
Data surfaces per spindle	1	1, 2	1, 2	1, 2	1, 2
Track density (TPI)	15875	34324	34324	34324	34324
Maximum linear density (BPI)	27600	96000	96000	96000	96000
PERFORMANCE					
Buffer/cache size (KBytes)	128	512	512	256	512
Average positioning time (msec)				100/80	
Average access time (msec)	130	110/80*	120/90*	110/90	130/90*
Data transfer rate (MBytes/sec) Internal	1.8/1.05**	8.3/4.8*	10.8/5.4*	5.4/4.8	5.4/4.8*
External		33 Ultra DMA	16.7		16.7 PIO Mode 4
SIZE (mm: H x W x D)	22.9 x 132.8 x 159	41.5 x 146 x 201	42 x 149 x 208	41.5 x 146 x 206	41.5 x 146 x 201
FIRST CUSTOMER SHIPMENT	6/98	5/99	3Q99	4/98	2/98
COMMENTS	*With PC card adapter. **Using Notebook power.	*CD-ROM mode. Reads DVD-R.	*CD-ROM mode.	MultiRead. *CD-ROM mode.	*CD-ROM mode.

MANUFACTURER	LG ELECTRONICS	LG ELECTRONICS	LG ELECTRONICS	LITE-ON TECHNOLOGY	LITE-ON TECHNOLOGY
CD FORMAT DRIVE	DRN-8040B	CED-8041B	CED-8042B	LTN-323	LTN-362
DISK/TREND GROUP	21	22	22	20	20
MARKET	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST
MEDIA: Recording technology	Replication	Phase Change	Phase Change	Replication	Replication
DRIVE: Drive type	DVD-ROM	CD-RW	CD-RW	CD-ROM	CD-ROM
Relative speed: Read	4X/24X*	24X	24X	32X max.	36X max.
Relative speed: Write	--	2X RW/4X R	4X	--	--
Rotational speed (RPM)					
Interface	IDE/ATAPI	IDE/ATAPI	IDE/ATAPI	IDE/ATAPI	IDE/ATAPI
Disk insertion	Tray	Tray	Tray	Tray	Tray
Speed control	CAV	CAV/CLV	CLV/CAV	CAV	CAV
CAPACITY/RECORDING DENSITY					
Nominal capacity (Gigabytes)	F: 4.7/8.5	F: .65	F: .65	F: .650	F: .65
Data surfaces per spindle	1, 2	1	1	1	1
Track density (TPI)	34324	15875	15875	15875	15875
Maximum linear density (BPI)	96000	27600	27600	27600	27600
PERFORMANCE					
Buffer/cache size (KBytes)	256	2000	2000	128	128
Average positioning time (msec)					
Average access time (msec)	180/130*	120	120	80	80
Data transfer rate (MBytes/sec) Internal	5.4/3.6*	3.6 max.	.6/3.6		4.8 max.
External					33 Ultra DMA
SIZE (mm: H x W x D)	12.7 x 128 x 129	41.5 x 146 x 201	41.5 x 146 x 201	41.5 x 146 x 191	41.3 x 145.8 x 190.5
FIRST CUSTOMER SHIPMENT	1Q99	2/98	4/99	1999	3Q98
COMMENTS	*CD-ROM mode.	MultiRead.			

MANUFACTURER	LITE-ON TECHNOLOGY	LITE-ON TECHNOLOGY	LITE-ON TECHNOLOGY	LITE-ON TECHNOLOGY	LITE-ON TECHNOLOGY
CD FORMAT DRIVE	LTN-382	LTN-403	LTN-405	LTN-443	LTN-483
DISK/TREND GROUP	20	20	20	20	20
MARKET	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST
MEDIA: Recording technology	Replication	Replication	Replication	Replication	Replication
DRIVE: Drive type	CD-ROM	CD-ROM	CD-ROM	CD-ROM	CD-ROM
Relative speed: Read	16X-40X	40X max.	40X max.	44X max.	48X max.
Relative speed: Write	--	--	--	--	--
Rotational speed (RPM)	8000		8250		
Interface	IDE/ATAPI	IDE/ATAPI	IDE/ATAPI	IDE/ATAPI	IDE/ATAPI
Disk insertion	Tray	Tray	Tray	Tray	Tray
Speed control	CAV	CAV	CAV	CAV	CAV
CAPACITY/RECORDING DENSITY					
Nominal capacity (Gigabytes)	F: .650	F: .650	F: .65	F: .650	F: .650
Data surfaces per spindle	1	1	1	1	1
Track density (TPI)	15875	15875	15875	15875	15875
Maximum linear density (BPI)	27600	27600	27600	27600	27600
PERFORMANCE					
Buffer/cache size (KBytes)	128	128	128	128	128
Average positioning time (msec)			80		
Average access time (msec)	80	80		80	80
Data transfer rate (MBytes/sec) Internal	2.4		6.0 max.		
External	6.0				
SIZE (mm: H x W x D)	41.3 x 145.8 x 190.5	41.5 x 146 x 191	41.3 x 146 x 191	41.5 x 146 x 191	41.5 x 146 x 191
FIRST CUSTOMER SHIPMENT	3Q98	1999	7/99	1999	1999
COMMENTS					

MANUFACTURER	LITE-ON TECHNOLOGY	LITE-ON TECHNOLOGY	LITE-ON TECHNOLOGY	LITE-ON TECHNOLOGY	LITE-ON TECHNOLOGY
CD FORMAT DRIVE	LTN-505	LTN-565	LTS-241	LTS-321	LTD-051
DISK/TREND GROUP	20	20	20	20	21
MARKET	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST
MEDIA: Recording technology	Replication	Replication	Replication	Replication	Replication
DRIVE: Drive type	CD-ROM	CD-ROM	CD-ROM	CD-ROM	DVD-ROM
Relative speed: Read	50X max.	56X max.	24X max.	32X max.	5.6X/32X*
Relative speed: Write	--	--	--	--	--
Rotational speed (RPM)	10000	13000		7000	7000
Interface	IDE/ATAPI	IDE/ATAPI	IDE/ATAPI	IDE/ATAPI	IDE/ATAPI
Disk insertion	Tray	Tray	Tray	Tray	Tray
Speed control	CAV	CAV	CAV	CAV	CAV
CAPACITY/RECORDING DENSITY					
Nominal capacity (Gigabytes)	F: .65	F: .65	F: .65	F: .65	F: 4.7/8.75
Data surfaces per spindle	1	1	1	1	1, 2
Track density (TPI)	15875	15875	15875	15875	34324
Maximum linear density (BPI)	27600	27600	27600	27600	96000
PERFORMANCE					
Buffer/cache size (KBytes)	128	128			256
Average positioning time (msec)	80	80			
Average access time (msec)			150	120	150
Data transfer rate (MBytes/sec) Internal	7.5 max.	8.4 max.	3.6 max.	4.8 max.	
External					33 Ultra DMA
SIZE (mm: H x W x D)	41.3 x 146 x 191	41.3 x 146 x 191	12.7 x 128 x 127	12.7 x 128 x 127	41.3 x 145.8 x 190.5
FIRST CUSTOMER SHIPMENT	7/99	7/99		1999	3Q99
COMMENTS					*CD-ROM mode.

MANUFACTURER	LITE-ON TECHNOLOGY	LITE-ON TECHNOLOGY	MATSUSHITA ELECTRIC INDUSTRIAL	MATSUSHITA ELECTRIC INDUSTRIAL	MATSUSHITA ELECTRIC INDUSTRIAL
CD FORMAT DRIVE	LTD-081	LTR-041	CR-175-B	CR-271-B	CR-586-B
DISK/TREND GROUP	21	22	20	20	20
MARKET	OEM, DIST	OEM, DIST	OEM	OEM	OEM
MEDIA: Recording technology	Replication	Replication	Replication	Replication	Replication
DRIVE: Drive type	DVD-ROM	CD-RW	CD-ROM	CD-ROM	CD-ROM
Relative speed: Read	8X/40X*	32X	10.3X-24X	10.3X-24X	14X-32X
Relative speed: Write	--	4X	--	--	--
Rotational speed (RPM)	8000	7000			7420
Interface	IDE/ATAPI	IDE/ATAPI	IDE/ATAPI	IDE/ATAPI	IDE/ATAPI
Disk insertion	Tray	Tray	Tray	Tray	Tray
Speed control	CAV	CAV	CAV	CAV	CAV
CAPACITY/RECORDING DENSITY					
Nominal capacity (Gigabytes)	F: 4.7/8.5	F: .65	F: .65	F: .65	F: .65
Data surfaces per spindle	1, 2	1	1	1	1
Track density (TPI)	34324	15875	15875	15875	15875
Maximum linear density (BPI)	96000	27600	27600	27600	27600
PERFORMANCE					
Buffer/cache size (KBytes)	256		128	128	256
Average positioning time (msec)	100				
Average access time (msec)			120	150	65
Data transfer rate (MBytes/sec) Internal	11/6.0*	.6/4.8	1.55-3.6	1.55-3.6	2.1-4.8
Data transfer rate (MBytes/sec) External			16.7 PIO Mode 4	16.7 PIO Mode 4	16.6 PIO Mode 4
SIZE (mm: H x W x D)	41.3 x 146 x 191		12.7 x 128 x 127	9.5 x 128 x 127	41.3 x 146 x 190
FIRST CUSTOMER SHIPMENT	9/99	1999	3Q98	3Q98	4Q97
COMMENTS	*CD-ROM mode.		MultiRead.	MultiRead.	

MANUFACTURER	MATSUSHITA ELECTRIC INDUSTRIAL	MATSUSHITA ELECTRIC INDUSTRIAL	MATSUSHITA ELECTRIC INDUSTRIAL	MATSUSHITA ELECTRIC INDUSTRIAL	MATSUSHITA ELECTRIC INDUSTRIAL
CD FORMAT DRIVE	CR-587	CR-588	CR-593-B	LK-RC832TZ	UJDA110
DISK/TREND GROUP	20	20	20	20	20
MARKET	OEM	OEM	OEM	DIST	OEM
MEDIA: Recording technology	Replication	Replication	Replication	Replication	Replication
DRIVE: Drive type	CD-ROM	CD-ROM	CD-ROM	CD-ROM	CD-ROM
Relative speed: Read	10.3X-24X	14X-32X	17.2X-40X	32X	20X
Relative speed: Write	--	--		--	--
Rotational speed (RPM)	5670	7420			
Interface	IDE/ATAPI	IDE/ATAPI	IDE/ATAPI	IDE/ATAPI	IDE/ATAPI
Disk insertion	Tray	Tray	Tray	Tray	Tray
Speed control	CAV	CAV	CAV	CAV	CAV
CAPACITY/RECORDING DENSITY					
Nominal capacity (Gigabytes)	F: .65	F: .65	F: .65	F: .650	F: .65
Data surfaces per spindle	1	1	1	1	1
Track density (TPI)	15875	15875	15875	15875	15875
Maximum linear density (BPI)	27600	27600	27600	27600	27600
PERFORMANCE					
Buffer/cache size (KBytes)	128	128	128		128
Average positioning time (msec)				65	
Average access time (msec)	100	100	85		150
Data transfer rate (MBytes/sec) Internal	1.55-3.6	2.1-4.8	2.55-6.0	2.06-4.8	3.0 max.
External	13.3 DMA Mode 1	16.6 PIO Mode 4	16.7 PIO Mode 4		
SIZE (mm: H x W x D)	41.3 x 146 x 190	41.3 x 146 x 190	41.3 x 146 x 190	41.3 x 146 x 196	12.7 x 128 x 132
FIRST CUSTOMER SHIPMENT	1Q98	2Q98	3Q99	2Q98	2Q97
COMMENTS				MultiRead.	Pin connector.

MANUFACTURER	MATSUSHITA ELECTRIC INDUSTRIAL	MATSUSHITA ELECTRIC INDUSTRIAL	MATSUSHITA ELECTRIC INDUSTRIAL	MATSUSHITA ELECTRIC INDUSTRIAL	MATSUSHITA ELECTRIC INDUSTRIAL
CD FORMAT DRIVE	UJDA130	UJDA150	SR-8171	SR-8173-B	SR-8583
DISK/TREND GROUP	20	20	21	21	21
MARKET	OEM	OEM	OEM	OEM	OEM, DIST
MEDIA: Recording technology	Replication	Replication	Replication	Replication	Replication
DRIVE: Drive type	CD-ROM	CD-ROM	DVD-ROM	DVD-ROM	DVD-ROM
Relative speed: Read	20X	24X	2X/20X*	4X/24X*	5X/32X*
Relative speed: Write	--	--	--		--
Rotational speed (RPM)					
Interface	IDE/ATAPI	IDE/ATAPI	IDE/ATAPI	IDE/ATAPI	IDE/ATAPI
Disk insertion	Tray	Tray	Tray		Tray
Speed control	CAV	CAV	CAV*/CLV	CAV	CAV*/CLV
CAPACITY/RECORDING DENSITY					
Nominal capacity (Gigabytes)	F: .65	F: .65	8.500 F: 4.700	F: 4.7/8.5	8.5 F: 4.7
Data surfaces per spindle	1	1	1, 2	1, 2	1, 2
Track density (TPI)	15875	15875	34324	34324	34324
Maximum linear density (BPI)	27600	27600	96000	96000	96000
PERFORMANCE					
Buffer/cache size (KBytes)	128	128	512	512	512
Average positioning time (msec)					
Average access time (msec)	150	150	180/120*	170/130*	140/90*
Data transfer rate (MBytes/sec) Internal	3.0	3.6 max.	1.4-2.8/1.3-3*	5.4/3.6*	6.75/4.8*
External				33 Ultra DMA	16.7 PIO Mode 4
SIZE (mm: H x W x D)	9.5 x 128 x 129	12.7 x 128 x 130	12.7 x 128 x 129	12.7 x 128 x 129	41.3 x 146 x 203
FIRST CUSTOMER SHIPMENT	7/98	1Q98	2Q98	2Q99	4Q98
COMMENTS		Pin connector.	*CD-ROM mode.	*CD-ROM mode. Reads DVD-R and DVD-RAM.	DVD-RAM compatible. *CD-ROM mode.

MANUFACTURER	MATSUSHITA ELECTRIC INDUSTRIAL	MATSUSHITA ELECTRIC INDUSTRIAL	MATSUSHITA ELECTRIC INDUSTRIAL	MATSUSHITA ELECTRIC INDUSTRIAL	MATSUSHITA ELECTRIC INDUSTRIAL
CD FORMAT DRIVE	SR-8584-B	CW-7503-B	CW-7582	KXL-RW10AN-S	LF-1002JB
DISK/TREND GROUP	21	22	22	22	22
MARKET	OEM, DIST	OEM	OEM	OEM, DIST	CAPT, DIST
MEDIA: Recording technology	Replication	Dye Polymer	Dye Polymer	Phase Change	Phase Change
DRIVE: Drive type	DVD-ROM	CD-R	CD-R	CD-RW	PD
Relative speed: Read	6X/32X*	20X	8X	20X	24X*
Relative speed: Write	--	8X	4X	4X	--
Rotational speed (RPM)			4240-800		2026
Interface	IDE/ATAPI	SCSI-2	IDE/ATAPI		SCSI-2
Disk insertion	Tray	Tray	Tray	Top	Tray
Speed control	CAV	CAV/CLV	CLV	CAV/CLV	ZCAV/CLV*
CAPACITY/RECORDING DENSITY					
Nominal capacity (Gigabytes)	F: 4.7/8.5	F: .65	F: .65	F: .65	F: .668 PD
Data surfaces per spindle	1, 2	1	1	1	1
Track density (TPI)	34324	15875	15875	15875	21166/15895*
Maximum linear density (BPI)	96000	27600	27600	27600	29195/27600*
PERFORMANCE					
Buffer/cache size (KBytes)		2000	1000	2000	640
Average positioning time (msec)					
Average access time (msec)		165	175		82/78*
Data transfer rate (MBytes/sec) Internal	8.1/4.8*	3.0/.9	.6 WR/1.2 RD	3.0/.6	.52-1.14
External	33.3 Ultra DMA				
SIZE (mm: H x W x D)	41.3 x 146 x 190	41.3 x 146 x 203	41.3 x 146 x	24.3 x 130 x 163	58 x 158 x 320
FIRST CUSTOMER SHIPMENT		2Q99	2Q98	5/99	4Q98
COMMENTS	*CD-ROM mode. Reads DVD-RAM and DVD-R media				*For CD-ROM mode.

MANUFACTURER	MATSUSHITA ELECTRIC INDUSTRIAL	MATSUSHITA ELECTRIC INDUSTRIAL	MATSUSHITA ELECTRIC INDUSTRIAL	MATSUSHITA ELECTRIC INDUSTRIAL	MATSUSHITA ELECTRIC INDUSTRIAL
CD FORMAT DRIVE	LF-102JA LF-102JD	LF-103JD	LF-1097 LF-1007	LF-1106 LF-1196	LF-1700
DISK/TREND GROUP	22	22	22	22	22
MARKET	OEM, DIST	OEM, DIST	CAPT,DIST,OEM	OEM, DIST	CAPT, DIST
MEDIA: Recording technology	Phase Change	Phase Change	Phase Change	Ph.Chg.,Replic.	Phase Change
DRIVE: Drive type	DVD-RAM	DVD-RAM	PD	PD	PD
Relative speed: Read	2X/20X**	2X/20X**	24X*	--/8X*	24X*
Relative speed: Write	1X*	1X*	--		--
Rotational speed (RPM)			2026	2026/4240-800*	2026
Interface	SCSI-2	SCSI-2	SCSI-2	IDE/ATAPI	SCSI-2
Disk insertion	Cartridge	Cartridge	Tray	Tray	Tray
Speed control	ZCAV	ZCAV	ZCAV/CLV*	ZCAV/CLV*	ZCAV/CLV*
CAPACITY/RECORDING DENSITY					
Nominal capacity (Gigabytes)	F: 2.6	F: 2.6	.668 PD F: .540 CD-ROM	.668 PD F: .540 CD-ROM	F: .668 PD
Data surfaces per spindle	1	1	1	1	1
Track density (TPI)	34324	34324	21166/15875*	21166/15875*	21166/15875*
Maximum linear density (BPI)	62000	62000	29195/27600*	29195/27600*	29195/27600*
PERFORMANCE					
Buffer/cache size (KBytes)	2000	2000	640	512	640
Average positioning time (msec)	120/85**/85	120/85**/85		88/195*	
Average access time (msec)			82/78*	102.8	82/78*
Data transfer rate (MBytes/sec) Internal External	1.37/1.14/3.0** 10.0 synch.	1.37/1.14/3.0** 10.0 synch.	.52-1.14/.6-.3*	.518-1.41/1.2* 11.1 PIO Mode 3	.52-1.14/.6-.3*
SIZE (mm: H x W x D)	50 x 168 x 245	41.3 x 146 x 196	41.3 x 146 x 196	41.3 x 146.1 x 196	35 x 143 x 218
FIRST CUSTOMER SHIPMENT	2Q99	2Q99	1Q98	3Q97	2Q98
COMMENTS	JA is for Apple Macintosh. External mount. *DVD-RAM mode. **CD-ROM mode.	*DVD-RAM mode. **CD-ROM mode.	*For CD-ROM mode.	*For CD-ROM mode.	*For CD-ROM mode.

MANUFACTURER	MATSUSHITA ELECTRIC INDUSTRIAL	MATSUSHITA ELECTRIC INDUSTRIAL	MATSUSHITA ELECTRIC INDUSTRIAL	MITSUMI ELECTRIC	MITSUMI ELECTRIC
CD FORMAT DRIVE	LF-D101 LF-D100J	LF-D111	UJDB310	CRMC-FX3210S	FX320M
DISK/TREND GROUP	22	22	22	20	20
MARKET	OEM, DIST	OEM, DIST	DIST	OEM, DIST	DIST
MEDIA: Recording technology	Phase Change	Phase Change	Phase Change	Replication	Replication
DRIVE: Drive type	DVD-RAM/PD	DVD-RAM/PD	CD-RW	CD-ROM	CD-ROM
Relative speed: Read	2X/--/20X**	2X/--/20X**		15X-32X	13X-32X
Relative speed: Write	1X*/--	1X*/--		4X R/2X RW	--
Rotational speed (RPM)					
Interface	SCSI-2	IDE/ATAPI		IDE/ATAPI	IDE/ATAPI
Disk insertion	Cartridge	Cartridge	Tray	Tray	Tray
Speed control	ZCAV/CLV	ZCAV/CLV	CLV	CAV	PCAV
CAPACITY/RECORDING DENSITY Nominal capacity (Gigabytes)	.668 PD F: 2.600	.668 PD F: 2.600	F: .65	F: .65	F: .65
Data surfaces per spindle	1	1	1	1	1
Track density (TPI)	34324	34324	15875	15875	15875
Maximum linear density (BPI)	62000	62000	27600	27600	27600
PERFORMANCE Buffer/cache size (KBytes)	2000	2000			256
Average positioning time (msec)					
Average access time (msec)	120*/85**/85	120*/85**/85		85	85
Data transfer rate (MBytes/sec) Internal External	1.37/1.14/3.0** 10.0 synch.	1.37/1.14/3** 16.7 PIO Mode 4		2.25-3.6	2.06-4.8
SIZE (mm: H x W x D)	41.3 x 146 x 196	41.3 x 146 x 196	12.7 x 128 x 130	42 x 148 x 201	41.3 x 148 x 201
FIRST CUSTOMER SHIPMENT	1Q98	1Q98		3Q98	1/98
COMMENTS	*DVD-RAM mode. **CD-ROM mode. MultiRead.	*DVD-RAM mode. **CD-ROM mode. MultiRead.			

MANUFACTURER	MITSUMI ELECTRIC	MITSUMI ELECTRIC	MITSUMI ELECTRIC	MITSUMI ELECTRIC	MITSUMI ELECTRIC
CD FORMAT DRIVE	FX332M	FX4010M	FX4820T	SR240S	SR242S
DISK/TREND GROUP	20	20	20	20	20
MARKET	OEM	OEM	OEM	OEM	OEM, DIST
MEDIA: Recording technology	Replication	Replication	Replication	Replication	Replication
DRIVE: Drive type	CD-ROM	CD-ROM	CD-ROM	CD-ROM	CD-ROM
Relative speed: Read	15X-32X	40X max.	48X max.	24X	10.5X-24X
Relative speed: Write	--	--	--	--	4X R/2X RW
Rotational speed (RPM)					
Interface	IDE/ATAPI	IDE	IDE	IDE/ATAPI	IDE/ATAPI
Disk insertion	Tray	Tray	Tray	Tray	Tray
Speed control	PCAV	PCAV	CAV	CAV	CAV
CAPACITY/RECORDING DENSITY					
Nominal capacity (Gigabytes)	F: .65	F: .65	F: .65	F: .65	F: .65
Data surfaces per spindle	1	1	1	1	1
Track density (TPI)	15875	15875	15875	15875	15875
Maximum linear density (BPI)	27600	27600	27600	27600	27600
PERFORMANCE					
Buffer/cache size (KBytes)	256	256	256	1000	
Average positioning time (msec)					
Average access time (msec)	75	80	75	120	120
Data transfer rate (MBytes/sec) Internal	2.25-4.8	6.0 max.	7.2 max.	3.6	1.58-3.6
External		33.3 Ultra DMA	33.3 Ultra DMA		
SIZE (mm: H x W x D)	41.3 x 148 x 201	41.3 x 148 x 201	41.3 x 148 x 201	12.7 x 128 x 129	12.7 x 128 x 129
FIRST CUSTOMER SHIPMENT	5/98	1998	1999	5/98	3Q98
COMMENTS					

MANUFACTURER	MITSUMI ELECTRIC	MITSUMI ELECTRIC	MOUNTAIN OPTECH	MOUNTAIN OPTECH	NAKAMICHI
CD FORMAT DRIVE	CR-4802TE	CR-4802TU	CS-680	SE-680 SI-680 ST-680	MJ-5.16S
DISK/TREND GROUP	22	22	20	20	20
MARKET	OEM, DIST	DIST	OEM	OEM	OEM, DIST
MEDIA: Recording technology	Phase Change	Phase Change	Replication	Replication	Replication
DRIVE: Drive type	CD-RW	CD-RW	CD-ROM	CD-ROM	CD-ROM
Relative speed: Read	8X	8X	32X max.	32X max.	16X
Relative speed: Write	4X R/2X RW	4X R/2X RW	--	--	--
Rotational speed (RPM)					
Interface	IDE/ATAPI	USB	SCSI-2	SCSI-2	SCSI-2
Disk insertion	Tray	Tray	Tray	Tray	Slot
Speed control	CLV	CLV	CLV	CLV	CAV
CAPACITY/RECORDING DENSITY					
Nominal capacity (Gigabytes)	F: .65	F: .65	F: .65	F: .65	F: .65/3.25
Data surfaces per spindle	1	1	1	1	1
Track density (TPI)	15875	15875	15875	15875	15875
Maximum linear density (BPI)	27600	27600	27600	27600	27600
PERFORMANCE					
Buffer/cache size (KBytes)	512	512	512	512	256
Average positioning time (msec)					
Average access time (msec)	200	200			120
Data transfer rate (MBytes/sec) Internal External	1.2/.6	1.2/.6	4.8 max. 10 synch.	4.8 max. 10 synch.	1.8-2.4
SIZE (mm: H x W x D)	41.3 x 146 x 205	53.5 x 194 x 255	41.3 x 146 x 203	41.3 x 146 x 203	43 x 149 x 222
FIRST CUSTOMER SHIPMENT	3Q98	2Q99	2Q99	2Q99	7/97
COMMENTS				Ruggedized CD-ROM.	5 disk library.

MANUFACTURER	NEC	NEC	NEC HOME ELECTRONICS	NEC HOME ELECTRONICS	NEC HOME ELECTRONICS
CD FORMAT DRIVE	ODX-658 Multi CD-R	ODX-653P	CDR-1810A	CDR-2800B	CDR-3000A
DISK/TREND GROUP	22	22	20	20	20
MARKET	OEM, DIST	OEM, DIST	OEM, Captive	OEM, Captive	OEM, Captive
MEDIA: Recording technology	Phase Change	Phase Change	Replication	Replication	Replication
DRIVE: Drive type	PD/CD-R	PD	CD-ROM	CD-ROM	CD-ROM
Relative speed: Read	--/20X*	--/6X*	12X-24X	10X-24X	17X-40X
Relative speed: Write	--/2X**		--	--	--
Rotational speed (RPM)	2027/1060/4000*	2026/3180-1200*		5300	8350
Interface	IDE/ATAPI	SCSI-2	SCSI-2	IDE/ATAPI	IDE/ATAPI
Disk insertion	Tray	Tray	Tray	Tray	Tray
Speed control	ZCAV/CAV/CLV	ZCAV/CLV*	CAV	CAV	CAV
CAPACITY/RECORDING DENSITY					
Nominal capacity (Gigabytes)	.664 PD F: .650 CD-ROM	.664 PD F: .650 CD-ROM	F: .65	F: .65	F: .65
Data surfaces per spindle	1	1	1	1	1
Track density (TPI)	21116/15875*	21116/15875*	15875	15875	15875
Maximum linear density (BPI)	29195/27600*	29195/27600*	27600	27600	27600
PERFORMANCE					
Buffer/cache size (KBytes)	512/1000*	256	256	128	128
Average positioning time (msec)		125/160*		130	85
Average access time (msec)	79		95		
Data transfer rate (MBytes/sec) Internal External	1.14/.3**/3.0* 5.3/16.4*	.518-1.14/.9*	1.8-3.6 20 synch.	1.5-3.6 33 Ultra DMA	1.2-3.0 16.6/33.2
SIZE (mm: H x W x D)	41.3 x 146 x 192	41.3 x 146 x 196	42.8 x 149 x 210	13.8 x 128 x 129	42.8 x 149 x 210
FIRST CUSTOMER SHIPMENT	2Q98	3Q96	1998	3Q98	1Q98
COMMENTS	*CD-ROM mode. **CD-R mode. MultiRead.	*CD-ROM mode.			MultiRead.

MANUFACTURER	NEC HOME ELECTRONICS	PAN-INTERNATIONAL (CYBERDRIVE)	PAN-INTERNATIONAL (CYBERDRIVE)	PAN-INTERNATIONAL (CYBERDRIVE)	PAN-INTERNATIONAL (CYBERDRIVE)
CD FORMAT DRIVE	CDR-3010	CD400D	CD480D	CS240D	DM832D
DISK/TREND GROUP	20	20	20	20	21
MARKET	OEM, Captive	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST
MEDIA: Recording technology	Replication	Replication	Replication	Replication	Replication
DRIVE: Drive type	CD-ROM	CD-ROM	CD-ROM	CD-ROM	DVD-ROM
Relative speed: Read	12X-24X	40X max.	48X max.	24X max.	5X/32X*
Relative speed: Write		--	--	--	--
Rotational speed (RPM)				5000-4800	3000/6500*
Interface	Ultra SCSI	IDE/ATAPI	IDE/ATAPI	IDE/ATAPI	IDE/ATAPI
Disk insertion	Tray	Tray	Tray	Tray	Tray
Speed control	CAV	CAV	CAV	ZCLV/CAV*	CAV
CAPACITY/RECORDING DENSITY					
Nominal capacity (Gigabytes)	F: .65			.630 Mode 2 F: .540 Mode 1	F: 4.7/8.5
Data surfaces per spindle	1	1	1	1	1, 2
Track density (TPI)	15875	15875	15875	15875	34324
Maximum linear density (BPI)	27600	27600	27600	27600	96000
PERFORMANCE					
Buffer/cache size (KBytes)	256	128	128	128	256
Average positioning time (msec)					
Average access time (msec)	85	90	80	125	120/100*
Data transfer rate (MBytes/sec) Internal	1.8-3.6	6.0 max.	7.2 max.	3.6 max.	6.75/4.8*
External	20 synch.				
SIZE (mm: H x W x D)	42.8 x 149 x 210	42 x 149 x 197	42 x 149 x 197	12.7 x 128 x 126.9	41.3 x 146 x 187.5
FIRST CUSTOMER SHIPMENT	1999	1Q99	1Q99	3Q98	1Q99
COMMENTS				*New release.	*CD-ROM mode.

MANUFACTURER	PAN-INTERNATIONAL (CYBERDRIVE)	PAN-INTERNATIONAL (CYBERDRIVE)	PAN-INTERNATIONAL (CYBERDRIVE)	PHILIPS	PHILIPS
CD FORMAT DRIVE	CD RW 602	CRD-R800SCD	CRD-RW1CD	PCA 20 PCA 24 PCA 32	DRD-5200
DISK/TREND GROUP	22	22	22	20	21
MARKET	OEM, DIST	OEM, DIST	OEM, DIST	DIST	DIST
MEDIA: Recording technology	Phase Change	Dye Polymer	Phase Change	Replication	Replication
DRIVE: Drive type	CD-RW	CD-R	CD-RW	CD-ROM	DVD-ROM
Relative speed: Read	6.4X max.	20X max.	20X max.	20X/32X	2X/24X*
Relative speed: Write	2X	8X	8X R/2X RW	--	--
Rotational speed (RPM)					
Interface	IDE/ATAPI	SCSI-2	SCSI-2	IDE/ATAPI	IDE/ATAPI
Disk insertion	Tray	Tray		Tray	Tray
Speed control	CLV	CAV/CLV	CAV/CLV	CAV/CLV	CAV/CLV
CAPACITY/RECORDING DENSITY					
Nominal capacity (Gigabytes)	.630 Mode 2 F: .540 Mode 1	F: .65	F: .65	F: .65	F: 4.7/8.5
Data surfaces per spindle	1	1	1	1	1, 2
Track density (TPI)	15875	15875	15875	15875	34324
Maximum linear density (BPI)	27600	27600	27600	27600	96000
PERFORMANCE					
Buffer/cache size (KBytes)	1024	2000	2000	256	
Average positioning time (msec)					
Average access time (msec)	310	180	220	110	160/110*
Data transfer rate (MBytes/sec) Internal External	.3 WR/.96RD max	3.0/1.2	3.0/1.2/.3	1.8-2.4 5.0	2.7/3.6*
SIZE (mm: H x W x D)	41.5 x 146 x 209.5	41.5 x 146 x 209.5	42.3 x 148.5 x 194.5	41.5 x 146 x 198	41.5 x 146 x 199
FIRST CUSTOMER SHIPMENT	4Q97	1Q99	1Q99	1998	4Q97
COMMENTS	MultiRead.			External mount option.	CD-RW + CD-R read compatible *CD-ROM mode.

MANUFACTURER	PHILIPS	PHILIPS	PHILIPS	PHILIPS	PHILIPS
CD FORMAT DRIVE	PCA 532DK	CD-RW 400	CDD 3600 PCA 350RW	CDD 3610 PCA 362RW OMNIwriter	CDD 3615 PCA 363RW
DISK/TREND GROUP	21	22	22	22	22
MARKET	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST
MEDIA: Recording technology	Replication	Phase Change	Phase Change	Phase Change	Phase Change
DRIVE: Drive type	DVD-ROM	CD-RW	CD-RW	CD-RW	CD-RW
Relative speed: Read	5X/32X*	16X	6X	6X	6X
Relative speed: Write		4X	2X	2X	2X
Rotational speed (RPM)			3180-400	3180-400	3180-400
Interface	IDE/ATAPI	IDE/ATAPI	SCSI-2	IDE/ATAPI	Parallel Port
Disk insertion	Tray	Tray	Tray	Tray	Tray
Speed control	CAV	CAV/CLV	CLV	CLV	CLV
CAPACITY/RECORDING DENSITY					
Nominal capacity (Gigabytes)	F: 4.7/8.5	F: .65	F: .65	F: .65	F: .65
Data surfaces per spindle	1, 2	1	1	1	1
Track density (TPI)	34324	15875	15875	15875	15875
Maximum linear density (BPI)	96000	27600	27600	27600	27600
PERFORMANCE					
Buffer/cache size (KBytes)		2000	1000	1000	1000
Average positioning time (msec)			290	290	290
Average access time (msec)			345 WR/310 RD	345 WR/310 RD	345 WR/310 RD
Data transfer rate (MBytes/sec) Internal	6.79/4.8*	2.4/.6	.307 WR/.921 RD	.307 WR/.921 RD	.307 WR/.921 RD
External			5.0 synch.		
SIZE (mm: H x W x D)			41.5 x 146 x 206	41.5 x 146 x 206	55 x 165 x 295
FIRST CUSTOMER SHIPMENT			4Q97	2Q97	2Q98
COMMENTS	*CD-ROM mode. Includes MPEG2 board.		Incremental packet writing.	Incremental packet writing. OMNIwriter is external mode.	External parallel version.

MANUFACTURER	PHILIPS	PHILIPS	PHILIPS	PHILIPS	PHILIPS
CD FORMAT DRIVE	CDD 3801	CDD 4201	CDD 4401	DVD+RW	PCA 351RW
DISK/TREND GROUP	22	22	22	22	22
MARKET	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST
MEDIA: Recording technology	Phase Change	Phase Change	Phase Change	Phase Change	Phase Change
DRIVE: Drive type	CD-RW	CD-RW	CD-RW	DVD+RW	CD-RW
Relative speed: Read	24X max.	24X max.	32X max.	1X	6X
Relative speed: Write	2X	4X	4X	1X	2X
Rotational speed (RPM)					3180-400
Interface	IDE/ATAPI	IDE/ATAPI	IDE/ATAPI	IDE/ATAPI	SCSI-2
Disk insertion	Tray	Tray	Tray	Tray	Tray
Speed control	CLV/CAV	CLV/CAV	CLV/CAV	CAV	CLV
CAPACITY/RECORDING DENSITY					
Nominal capacity (Gigabytes)	F: .65	F: .65	F: .65	F: 3.0	F: .65
Data surfaces per spindle	1	1	1	1	1
Track density (TPI)	15875	15875	15875		15875
Maximum linear density (BPI)	27600	27600	27600		27600
PERFORMANCE					
Buffer/cache size (KBytes)	2000	2000	2000		1000
Average positioning time (msec)					290
Average access time (msec)	125	125	125		345 WR/310 RD
Data transfer rate (MBytes/sec) Internal External	.3/3.6	.6/3.6	.6/4.8	1.65	.307 WR/.921 RD
SIZE (mm: H x W x D)	41.5 x 146 x 206	41.5 x 146 x 206	41.5 x 146 x 206		55 x 165 x 295
FIRST CUSTOMER SHIPMENT				9/99	2Q98
COMMENTS				Preliminary specification.	External SCSI version.

MANUFACTURER	PHILIPS	PIONEER	PIONEER	PIONEER	PIONEER
CD FORMAT DRIVE	PCRW 404K	DRM-GNX	DVD-303S	DVD-303X	DVD-303Y
DISK/TREND GROUP	22	20	21	21	21
MARKET	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST
MEDIA: Recording technology	Phase Change	Replication	Replication	Replication	Replication
DRIVE: Drive type	CD-RW	CD-ROM*	DVD-ROM	DVD-ROM	DVD-ROM
Relative speed: Read	32X	24X	6X/32X*	6X/32X*	6X/32X*
Relative speed: Write	4X	--	--	--	--
Rotational speed (RPM)					
Interface	IDE/ATAPI	Ethernet	Ultra SCSI	IDE/ATAPI	IDE/ATAPI
Disk insertion	Tray	Magazine	Tray	Tray	Slot
Speed control	CLV/CAV	CAV	CAV	CAV	CAV
CAPACITY/RECORDING DENSITY					
Nominal capacity (Gigabytes)	F: .65	F: .65	F: 4.7/8.5	F: 4.7/8.5	F: 4.7/8.5
Data surfaces per spindle	1	1	1, 2	1, 2	1, 2
Track density (TPI)	15875	15875	34324	34324	34324
Maximum linear density (BPI)	27600	27600	96000	96000	96000
PERFORMANCE					
Buffer/cache size (KBytes)	2000	**	512	512	512
Average positioning time (msec)			90/70*	90/70*	90/70*
Average access time (msec)		75	120/80*	120/80*	120/80*
Data transfer rate (MBytes/sec) Internal	.6/4.8*	1.8-3.6	8.1/4.8	8.1/4.8	8.1/4.8
External			20 synch.	33.3 Ultra DMA	33.3 Ultra DMA
SIZE (mm: H x W x D)		153 x 212 x 439.2	42.3 x 148 x 208.5	42.3 x 148 x 208.5	42.3 x 148 x 208.5
FIRST CUSTOMER SHIPMENT	3Q99	1999	1Q99	1Q99	1Q99
COMMENTS	*CD-ROM mode.	*6 disk autochanger. Network attached, RDD buffer. **5.1 GB	*CD-ROM mode.	*CD-ROM mode.	*CD-ROM mode.

MANUFACTURER	PIONEER	PIONEER	PIONEER	PIONEER	PIONEER
CD FORMAT DRIVE	DVD-A03S	DVD-A13	DVD-U03S	DR-R504X	DVR-S101
DISK/TREND GROUP	21	21	21	22	22
MARKET	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST
MEDIA: Recording technology	Replication	Replication	Replication	Dye Polymer	Dye Polymer
DRIVE: Drive type	DVD-ROM	DVD-ROM	DVD-ROM	CD-R	DVD-R
Relative speed: Read	6X/32X*	6X/32X*	6X/32X*	4X	1X
Relative speed: Write	--	--	--		1X
Rotational speed (RPM)				2120-800	
Interface	IDE/ATAPI	IDE/ATAPI	Ultra SCSI		SCSI-2
Disk insertion	Slot	Tray	Slot		Tray
Speed control	CAV	CAV	CAV	CLV	CLV
CAPACITY/RECORDING DENSITY					
Nominal capacity (Gigabytes)	F: 4.7/8.5	F: 4.7/8.5	F: 4.7/8.5	F: .550	F: 3.95
Data surfaces per spindle	1, 2	1, 2	1, 2	1	1
Track density (TPI)	34324	34324	34324	15875	31750
Maximum linear density (BPI)	96000	96000	96000	27600	56000
PERFORMANCE					
Buffer/cache size (KBytes)	512	512	512	1000	4000
Average positioning time (msec)	100/80*	100/80*	100/80*	110	
Average access time (msec)	120/90*	120/90*	120/90*	137	
Data transfer rate (MBytes/sec) Internal	3.3-8.1/4.8 max	3.3-8.1/4.8 max	3.3-8.1/4.8 max	.614	1.428
External	33.3 Ultra DMA	33.3 Ultra DMA	20 synch.		
SIZE (mm: H x W x D)	42.3 x 148 x 207.5	42.3 x 148 x 207.5	42.3 x 148 x 207.5	41.3 x 146 x 203	115 x 210 x 399
FIRST CUSTOMER SHIPMENT	1Q99	1Q99	1Q99	1Q95	1Q98
COMMENTS	*CD-ROM mode.	*CD-ROM mode.	*CD-ROM mode.	For use with CD library.	

MANUFACTURER	PIONEER	PIONEER	PLEXTOR (SHINANO KENSHI)	PLEXTOR (SHINANO KENSHI)	PLEXTOR (SHINANO KENSHI)
CD FORMAT DRIVE	DVR-S201	DW-S114X	PX-32CS	PX-32TS	PX-40TSi PX-40TSe
DISK/TREND GROUP	22	22	20	20	20
MARKET	OEM, DIST	OEM	OEM, DIST	OEM, DIST	OEM, DIST
MEDIA: Recording technology	Dye Polymer	Dye Polymer	Replication	Replication	Replication
DRIVE: Drive type	DVD-R	CD-R	CD-ROM	CD-ROM	CD-ROM
Relative speed: Read	1X	4X	14X-32X	14X-32X	17.3X-40X
Relative speed: Write	1X		--	--	--
Rotational speed (RPM)	575-1623	2120-800	6890	6890	8590
Interface	SCSI-2	SCSI-2	Ultra SCSI	Ultra SCSI	Ultra SCSI
Disk insertion	Tray	Tray	Caddy	Tray	Tray
Speed control	CLV	CLV	CAV	CAV	CAV
CAPACITY/RECORDING DENSITY					
Nominal capacity (Gigabytes)	F: 3.95/4.7	F: .550	F: .65	F: .65	F: .65
Data surfaces per spindle	1	1	1	1	1
Track density (TPI)	31750/34324	15875	15875	15875	15875
Maximum linear density (BPI)	56000/96000	27600	27600	27600	27600
PERFORMANCE					
Buffer/cache size (KBytes)	4000	1000	512	512	512
Average positioning time (msec)		603	80	80	80
Average access time (msec)		630	85	85	85
Data transfer rate (MBytes/sec) Internal External	1.428	.614	2.1-4.8 20.0 synch.	2.1-4.8 20.0 synch.	2.55-6.0 20 synch.
SIZE (mm: H x W x D)	41.3 x 146 x 203	41.3 x 146 x 203	41.3 x 146 x 202	41.3 x 146 x 202	41.6 x 146.8 x 201.9
FIRST CUSTOMER SHIPMENT	3Q99	3Q95	1998	1998	1998
COMMENTS			MultiRead.	MultiRead.	e is external mount.

MANUFACTURER	PLEXTOR (SHINANO KENSHI)	PLEXTOR (SHINANO KENSHI)	PLEXTOR (SHINANO KENSHI)	PLEXTOR (SHINANO KENSHI)	PLEXTOR (SHINANO KENSHI)
CD FORMAT DRIVE	PX-40TSUWi	PX-50TSi PX-50TSe	PX-50TSUWi	PX-8220Ti PX-8220Te	PX-R412Ce PX-R412Ci
DISK/TREND GROUP	20	20	20	22	22
MARKET	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST	DIST
MEDIA: Recording technology	Replication	Replication	Replication	Phase Change	Dye Polymer
DRIVE: Drive type	CD-ROM	CD-ROM	CD-ROM	CD-RW	CD-R
Relative speed: Read	17.3X-40X	21.6X-50X	21.6X-50X	9X-20X	8X-12X
Relative speed: Write	--	--		2X RW/8X R	4X
Rotational speed (RPM)	8590	10700	10700	1600-4600	6360-800
Interface	Ultra SCSI*	Ultra SCSI	Ultra SCSI*	SCSI-2	SCSI-2
Disk insertion	Tray	Tray	Tray	Tray	Caddy*
Speed control	CAV	CAV	CAV	CLV/CAV	CLV/PCAV
CAPACITY/RECORDING DENSITY					
Nominal capacity (Gigabytes)	F: .65	F: .65	F: .65	F: .65	F: .65
Data surfaces per spindle	1	1	1	1	1
Track density (TPI)	15875	15875	15875	15875	15875
Maximum linear density (BPI)	27600	27600	27600	27600	27600
PERFORMANCE					
Buffer/cache size (KBytes)	512	512	512	4000	2000
Average positioning time (msec)	80	80	85		
Average access time (msec)	85	85	80	170	190
Data transfer rate (MBytes/sec) Internal	2.55-6.0	3.24-7.5	3.24-7.5	1.35-3.0/1.2	.6 WR/1.8 RD
External	40 synch.	20 synch.	40 synch.	10 synch.	10.0 synch.
SIZE (mm: H x W x D)	41.6 x 146.8 x 201.9	41.6 x 146.8 x 201.9	41.6 x 146.8 x 201.9	41.6 x 146.8 x 201.9	41.3 x 146 x 205
FIRST CUSTOMER SHIPMENT	1998	2Q99	2Q99	2Q99	1Q98
COMMENTS	*Ultra SCSI wide.		*Ultra SCSI wide.	e is external mount.	Ce model is external mount. *With tray adapter.

MANUFACTURER	PLEXTOR (SHINANO KENSHI)	PLEXTOR (SHINANO KENSHI)	PLEXTOR (SHINANO KENSHI)	RAITE OPTOELECTRONICS	RAITE OPTOELECTRONICS
CD FORMAT DRIVE	PX-R412CS	PX-R820Ti PX-R820Te	PX-W4220Ti PX-W4220Te	RDR-102 AVBravo 102	RDR-105 AVBravo 105
DISK/TREND GROUP	22	22	22	21	21
MARKET	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST
MEDIA: Recording technology	Dye Polymer	Dye Polymer	Phase Change	Replication	Replication
DRIVE: Drive type	CD-R	CD-R	CD-RW	DVD-ROM	DVD-ROM
Relative speed: Read	12X	9X-20X	9X-20X	2X/24X*	5X/32X*
Relative speed: Write	4X	8X	2X RW/4X R	--	--
Rotational speed (RPM)	6360-800	1600-4600	1600-4600		
Interface	SCSI-2	SCSI-2	SCSI-2	IDE/ATAPI	IDE/ATAPI
Disk insertion	Caddy	Tray	Tray	Tray	Tray
Speed control	CLV/PCAV	CLV/CAV	CLV/CAV	CLV/CAV	CAV
CAPACITY/RECORDING DENSITY					
Nominal capacity (Gigabytes)	F: .65	F: .65	F: .65	F: 4.7/8.5	F: 4.7/8.5
Data surfaces per spindle	1	1	1	1, 2	1, 2
Track density (TPI)	15875	15875	15875	34324	34324
Maximum linear density (BPI)	27600	27600	27600	96000	96000
PERFORMANCE					
Buffer/cache size (KBytes)	2000	4000	2000	512	512
Average positioning time (msec)					
Average access time (msec)	190	170	170	150/100*	130/95*
Data transfer rate (MBytes/sec) Internal	.6 WR/1.8 RD	1.35-3.0/1.2	1.35-3.0/.6	2.76/3.6*	7.0/4.8*
External	10 synch.	10 synch.	10 synch.		
SIZE (mm: H x W x D)	41.3 x 146 x 205	41.6 x 146.8 x 201.9	41.6 x 146.8 x 201.9	41.5 x 146 x 200	42.8 x 149 x 211
FIRST CUSTOMER SHIPMENT	1998	1998	1998	1998	1999
COMMENTS		e is external mount.	e is external mount.	Purchased mechanism. *CD-ROM mode.	Purchased mechanism. *CD-ROM mode.

MANUFACTURER	RAITE OPTOELECTRONICS	RICOH	RICOH	RICOH	RICOH
CD FORMAT DRIVE	RDR-106H AVBravo 106	MP7040A-ED	MP7040S-DP	MP7060A	MP7060S
DISK/TREND GROUP	21	22	22	22	22
MARKET	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST
MEDIA: Recording technology	Replication	Phase Change	Phase Change	Phase Change	Phase Change
DRIVE: Drive type	DVD-ROM	CD-RW	CD-RW	CD-RW	CD-RW
Relative speed: Read	6.2X/32X*	20X	20X	24X	24X
Relative speed: Write	--	4X	4X	6X R, 4X RW	6X R, 4X RW
Rotational speed (RPM)		2120-800/4800*	2120-800/4800*		
Interface	IDE/ATAPI	ATAPI	SCSI-2	ATAPI	SCSI-2
Disk insertion	Tray	Tray	Tray	Tray	Tray
Speed control	CAV	CLV/CAV*	CLV/CAV*	CLV/CAV*	CLV/CAV*
CAPACITY/RECORDING DENSITY					
Nominal capacity (Gigabytes)	F: 4.7/8.5	F: .65	F: .65	F: .65	F: .65
Data surfaces per spindle	1, 2	1	1	1	1
Track density (TPI)	34324	15875	15875	15875	15875
Maximum linear density (BPI)	96000	27600	27600	27600	27600
PERFORMANCE					
Buffer/cache size (KBytes)	512	2000	2000	2000	2000
Average positioning time (msec)					
Average access time (msec)	130/95*	120*	120*	120*	120*
Data transfer rate (MBytes/sec) Internal	8.3/4.8*	.6/3.0	.6/3.0	.6/.9/3.6	.6/.9/3.6
External		16.7	8.0 synch.	11.1	8.0 synch.
SIZE (mm: H x W x D)	42.8 x 149 x 211	41.3 x 146 x 193	41.3 x 146 x 193	41.3 x 146 x 193	41.3 x 146 x 193
FIRST CUSTOMER SHIPMENT	1999	1/99	1/99	6/99	6/99
COMMENTS	Purchased mechanism. *CD-ROM mode.	*CD-ROM mode.	*CD-ROM mode.	*CD-ROM mode.	*CD-ROM mode.

MANUFACTURER	RICOH	SAMSUNG ELECTRONICS	SAMSUNG ELECTRONICS	SAMSUNG ELECTRONICS	SAMSUNG ELECTRONICS
CD FORMAT DRIVE	MP8040SE	SC-140	SC-148	SCR-2437	SCR-2438E
DISK/TREND GROUP	22	20	20	20	20
MARKET	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST
MEDIA: Recording technology	Phase Change	Replication	Replication	Replication	Replication
DRIVE: Drive type	CD-RW	CD-ROM	CD-ROM	CD-ROM	CD-ROM
Relative speed: Read	20X	16.6X-40X	20X-48X	10X-24X	24X
Relative speed: Write	4X	--	--	--	--
Rotational speed (RPM)		8300	9600		
Interface	SCSI-2/PCMCIA	IDE/ATAPI	IDE/ATAPI	IDE/ATAPI	IDE/ATAPI
Disk insertion	Top Loading	Tray	Tray	Tray	Tray
Speed control	CLV/CAV*	CAV	CAV	CAV	CAV
CAPACITY/RECORDING DENSITY					
Nominal capacity (Gigabytes)	F: .65	F: .65	F: .65	F: .65	F: .65
Data surfaces per spindle	1	1	1	1	1
Track density (TPI)	15875	15875	15875	15875	15875
Maximum linear density (BPI)	27600	27600	27600	27600	27600
PERFORMANCE					
Buffer/cache size (KBytes)	2000	128	128	256	128
Average positioning time (msec)				130	
Average access time (msec)	150*	80	80		110
Data transfer rate (MBytes/sec) Internal	.6/.9/3.6	2.49-6.0	3.0-7.2	1.5-3.6	3.6 max.
External	16.7	33.3 Ultra DMA	33.3 Ultra DMA	16.7 PIO Mode 4	
SIZE (mm: H x W x D)			42.5 x 149 x 200	12.7 x 128 x 129	
FIRST CUSTOMER SHIPMENT	8/99	2/99		1Q98	
COMMENTS	*CD-ROM mode. Preliminary spec. External mount.	MultiRead.	MultiRead.	MultiRead.	

MANUFACTURER	SAMSUNG ELECTRONICS	SAMSUNG ELECTRONICS	SAMSUNG ELECTRONICS	SAMSUNG ELECTRONICS	SAMSUNG ELECTRONICS
CD FORMAT DRIVE	SCR-3230	SCR-3231	SCR-3232E	SN-124	SD-604
DISK/TREND GROUP	20	20	20	20	21
MARKET	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST
MEDIA: Recording technology	Replication	Replication	Replication	Replication	Replication
DRIVE: Drive type	CD-ROM	CD-ROM	CD-ROM	CD-ROM	DVD-ROM
Relative speed: Read	12.8X-32X	12.8X-32X	32X	10X-24X	5X/32X*
Relative speed: Write	--	--		--	--
Rotational speed (RPM)					
Interface	IDE/ATAPI	IDE/ATAPI	IDE/ATAPI	IDE/ATAPI	IDE/ATAPI
Disk insertion	Tray	Tray	Tray	Tray	Tray
Speed control	CAV	CAV	CAV	CAV	CAV
CAPACITY/RECORDING DENSITY					
Nominal capacity (Gigabytes)	F: .65	F: .65	F: .65	F: .65	F: 4.7/8.5
Data surfaces per spindle	1	1	1	1	1, 2
Track density (TPI)	15875	15875	15875	15875	34324
Maximum linear density (BPI)	27600	27600	27600	27600	96000
PERFORMANCE					
Buffer/cache size (KBytes)	512	512	128	128	512
Average positioning time (msec)	80	90			
Average access time (msec)			90		110/90*
Data transfer rate (MBytes/sec) Internal	1.92-4.8	1.92-4.8	4.8 max.	3.6	6.75/4.8*
External	16.7 PIO Mode 4	16.7 PIO Mode 4		16.6 PIO Mode 4	16.6 PIO Mode 4
SIZE (mm: H x W x D)	41.3 x 149 x 202	41.3 x 149 x 202		12.7 x 128 x 129	42.5 x 149 x 200
FIRST CUSTOMER SHIPMENT	1Q98	2Q98			
COMMENTS	MultiRead.	MultiRead.			*CD-ROM mode. MultiRead.

MANUFACTURER	SAMSUNG ELECTRONICS	SAMSUNG ELECTRONICS	SAMSUNG ELECTRONICS	SAMSUNG ELECTRONICS	SAMSUNG ELECTRONICS
CD FORMAT DRIVE	SD-606	SD-608	SDR-430	SN-606	SCW-230
DISK/TREND GROUP	21	21	21	21	22
MARKET	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST
MEDIA: Recording technology	Replication	Replication	Replication	Replication	Phase Change
DRIVE: Drive type	DVD-ROM	DVD-ROM	DVD-ROM	DVD-ROM	CD-RW
Relative speed: Read	6X/32X*	8X/32X*	4X/32X*	6X/24X*	6X
Relative speed: Write	--	--	--	--	2X
Rotational speed (RPM)				4800	3180-400
Interface	IDE/ATAPI	IDE/ATAPI	IDE/ATAPI	IDE/ATAPI	
Disk insertion	Tray	Tray	Tray	Tray	
Speed control	CAV	CAV		CAV	CLV
CAPACITY/RECORDING DENSITY					
Nominal capacity (Gigabytes)	F: 4.7/8.5	F: 4.7/8.5	8.500 F: 4.700	F: .65/4.7/8.5	F: .650
Data surfaces per spindle	1, 2	1, 2	1, 2	1, 2	1
Track density (TPI)	34324	34324	34324	15875/34324	15875
Maximum linear density (BPI)	96000	96000	96000	27600/96000	27600
PERFORMANCE					
Buffer/cache size (KBytes)	512	512	512	512	1000
Average positioning time (msec)			150/100		
Average access time (msec)	110/90*	110/90*		150/110*	350
Data transfer rate (MBytes/sec) Internal	8.1/4.8*	10.8/4.8	5.4/4.8*	8.1/3.6*	.9 RD/.3 WR
External	16.6 PIO Mode 4	16.6 PIO Mode 4			
SIZE (mm: H x W x D)	42.5 x 149 x 200	42.5 x 149 x 200	41.5 x 149 x 199	12.7 x 128 x 129	41.5 x 146 x 206
FIRST CUSTOMER SHIPMENT			1998		1Q98
COMMENTS	*CD-ROM mode. MultiRead.	*CD-ROM mode. MultiRead.	*CD-ROM. MultiRead.	*CD-ROM mode.	

MANUFACTURER	SAMSUNG ELECTRONICS	SAMSUNG ELECTRONICS	SAMSUNG ELECTRONICS	SAMSUNG ELECTRONICS	SANYO ELECTRIC
CD FORMAT DRIVE	SM-304	SR-702	SW-204	SW-208	CRD-1332P
DISK/TREND GROUP	22	22	22	22	20
MARKET	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST
MEDIA: Recording technology	Phase Change	Phase Change	Phase Change	Phase Change	Replication
DRIVE: Drive type	CD-RW/DVD-ROM	CD-RW/DVD-RAM	CD-RW	CD-RW	CD-ROM
Relative speed: Read	6X*/32X**	4X/24X*/32X**	24X	32X	13X-32X
Relative speed: Write	4X	2X/4X	4X W/2X RW	8X W/4X RW	--
Rotational speed (RPM)					6890
Interface	IDE/ATAPI	IDE/ATAPI	IDE/ATAPI	IDE/ATAPI	IDE/ATAPI
Disk insertion	Tray	Tray	Tray	Tray	Tray
Speed control	CAV/CLV	CAV/CLV	CAV/CLV	CAV/CLV	CAV
CAPACITY/RECORDING DENSITY					
Nominal capacity (Gigabytes)	F: .65/4.7	F: .65/2.6/4.7	F: .65	F: .65	F: .640
Data surfaces per spindle	1, 2*	1, 2	1	1	1
Track density (TPI)	15875/34324	15875/34324	15875	15875	15875
Maximum linear density (BPI)	27600/96000	27600/62000	27600	27600	27600
PERFORMANCE					
Buffer/cache size (KBytes)	2000	2000	2048	2048	128
Average positioning time (msec)					100
Average access time (msec)	110*/90**	150/90**	100	100	
Data transfer rate (MBytes/sec) Internal	.6/8.1*/4.8**	2.7/5.4/4.8**	.6/.3/3.6	1.2/.6/4.8	1.95-4.8
Data transfer rate (MBytes/sec) External	33.3 Ultra DMA		16.6 PIO Mode 4	33.3 Ultra DMA	
SIZE (mm: H x W x D)	42.5 x 149 x 200	42.5 x 149 x 200	42.5 x 149 x 200	42.5 x 149 x 200	41 x 146 x 190
FIRST CUSTOMER SHIPMENT					4Q97
COMMENTS	*DVD-ROM mode. **CD-ROM mode.	*CD-RW mode. **CD-ROM mode.	MultiRead.	MultiRead.	

MANUFACTURER	SANYO ELECTRIC	SANYO ELECTRIC	SONY	SONY	SONY
CD FORMAT DRIVE	CRD-R800S	CRD-RW1N	CDU701	PRD-250WN	PRD-650MC PRD-650WN CD-ROM Discman
DISK/TREND GROUP	22	22	20	20	20
MARKET	OEM, DIST	OEM, DIST	OEM, DIST	DIST	DIST
MEDIA: Recording technology	Dye Polymer	Phase Change	Replication	Replication	Replication
DRIVE: Drive type	CD-R	CD-RW	CD-ROM	CD-ROM	CD-ROM
Relative speed: Read	20X	8X-20X	32X	4X	6X
Relative speed: Write	8X	8X R/2X RW	--	--	--
Rotational speed (RPM)		4000-1060	7000	2120-800	3180-1200
Interface	SCSI-2	SCSI-2	IDE/ATAPI	PCMCIA	PCMCIA
Disk insertion		Tray	Tray		
Speed control		CAV/CLV	CAV	CLV	CLV
CAPACITY/RECORDING DENSITY					
Nominal capacity (Gigabytes)	F: .640	F: .65	F: .65	F: .540	.650 Mode 2 F: .553 Mode 1
Data surfaces per spindle	1	1	1	1	1
Track density (TPI)	15875	15875	15875	15875	15875
Maximum linear density (BPI)	27600	27600	27600	27600	27600
PERFORMANCE					
Buffer/cache size (KBytes)	128	2000	128	128	128
Average positioning time (msec)	150			250	280/128*
Average access time (msec)		180	90	277	
Data transfer rate (MBytes/sec) Internal External	1.2 WR/3.0 RD	1.2-3.0/1.2/.3	4.8 16.7PIO/33UDMA	.600	.6/.9*
SIZE (mm: H x W x D)	42.3 x 148.5 x 191.1	42.3 x 148.5 x 194.5	41.4 x 146 x 203	27 x 132 x 172	
FIRST CUSTOMER SHIPMENT	1Q98		2Q98	1996	4Q96
COMMENTS					Portable. *With PC adapter.

MANUFACTURER	SONY	SONY	SONY	SONY	SONY
CD FORMAT DRIVE	SCPH1075 Playstation	DDU-100E	DDU-220E DDU-220E/H	DDU220E-06 DDU220E/H2	CDU948S CDU948S/CH
DISK/TREND GROUP	20	21	21	21	22
MARKET	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST
MEDIA: Recording technology	Replication	Replication	Replication	Replication	Dye Polymer
DRIVE: Drive type	CD-ROM	DVD-ROM	DVD-ROM	DVD-ROM	CD-R
Relative speed: Read	--	1X/8X*	5X/32X*	6X/32X*	8X
Relative speed: Write	--	--	--	--	4X
Rotational speed (RPM)	NS		7000-2800	7000-3360	4240-800
Interface	Proprietary	IDE/ATAPI	IDE/ATAPI	IDE/ATAPI	SCSI-2
Disk insertion		Tray	Tray	Tray	Caddy
Speed control	CLV	CLV	PCAV/CAV*	PCAV/CAV	CLV
CAPACITY/RECORDING DENSITY Nominal capacity (Gigabytes)	F: .650 Mode 2 .553 Mode 1	F: 4.700/8.500	F: 8.5 4.7	F: 8.5 4.7	F: .65
Data surfaces per spindle	1	1, 2	1, 2	1, 2	1
Track density (TPI)	15875	34324	34284	34284	15875
Maximum linear density (BPI)	27600	96000	96000	96000	27600
PERFORMANCE Buffer/cache size (KBytes)		512	512	512	2000
Average positioning time (msec)	NS				
Average access time (msec)	NS		100/75*	115/100*	220
Data transfer rate (MBytes/sec) Internal External	.300	1.35/1.2* 16.7 PIO Mode 4	6.75/4.8*	8.1/4.8	4.8
SIZE (mm: H x W x D)	60 x 270 x 188	41.4 x 146 x 203	41.4 x 146 x 203	41.3 x 146 x 203	41.4 x 146 x 203
FIRST CUSTOMER SHIPMENT	4Q94	1Q97	6/98	2Q99	1Q98
COMMENTS		*CD-ROM mode. Dual laser pickup.	*CD-ROM mode. E/H model includes MPEG card.	*CD-ROM mode. E/H model includes MPEG card.	

MANUFACTURER	SONY	SONY	SONY	SONY	SONY
CD FORMAT DRIVE	CRX100E/CH Spressa	CRX100E/X Spressa CD-RW	CRX120E	CRX120E/C Spressa CD-RW	CRX120E/X i.LINK Spressa i.LINK
DISK/TREND GROUP	22	22	22	22	22
MARKET	DIST	DIST	OEM	DIST	DIST
MEDIA: Recording technology	Phase Change	Phase Change	Phase Change	Phase Change	Phase Change
DRIVE: Drive type	CD-RW	CD-RW	CD-RW	CD-RW	CD-RW
Relative speed: Read	24X	8X	24X	24X	24X
Relative speed: Write	2X RW/4X R	2X (RW)/4X (R)	4X R, 4X RW	4X	4X
Rotational speed (RPM)		4240-1060			
Interface	IDE/ATAPI	USB	ATAPI	IDE/ATAPI	P1394
Disk insertion	Tray	Tray	Tray	Tray	Tray
Speed control	CAV*/CLV	CLV	CLV/CAV	CLV/CAV	CLV/CAV
CAPACITY/RECORDING DENSITY					
Nominal capacity (Gigabytes)	F: .65	F: .65	F: .65	F: .65	F: .65
Data surfaces per spindle	1	1	1	1	1
Track density (TPI)	15875	15875	15875	15875	15875
Maximum linear density (BPI)	27600	27600	27600	27600	27600
PERFORMANCE					
Buffer/cache size (KBytes)	1000	1000	2000	2000	2000
Average positioning time (msec)					
Average access time (msec)	150	150	150	150	150
Data transfer rate (MBytes/sec) Internal	3.6*/.6/.3	.3/.6/1.2	.6/3.6		.6/3.6
External	16.6 PIO Mode 4	1.4	16.7		11.1
SIZE (mm: H x W x D)		61 x 191 x 257	41.4 x 146.0 x 203.0		61 x 191 x 257
FIRST CUSTOMER SHIPMENT	3Q98	3/99	2Q99	5/99	6/99
COMMENTS	*CD-ROM mode.	External mount.			External mount. For Macintosh.

MANUFACTURER	SONY	SONY	SONY	TATUNG	TATUNG
CD FORMAT DRIVE	CRX50A	CRX510E	DRX101S/C	CD-1640E	CD-1648E
DISK/TREND GROUP	22	22	22	20	20
MARKET	OEM, DIST	OEM	OEM, DIST	OEM, DIST	OEM, DIST
MEDIA: Recording technology	Dye Polymer	Dye Polymer	Phase Change	Replication	Replication
DRIVE: Drive type	CD-R	CD-R	DVD+RW	CD-ROM	CD-ROM
Relative speed: Read	20	20X	2.5X/24X*	40X	48X
Relative speed: Write	4	4X R	1.25X	--	--
Rotational speed (RPM)					
Interface	IDE	ATAPI	SCSI-2	IDE/ATAPI	IDE/ATAPI
Disk insertion	Drawer	Drawer	Tray	Tray	Tray
Speed control	CLV/CAV*	CLV/CAV	CAV	CAV	CAV
CAPACITY/RECORDING DENSITY					
Nominal capacity (Gigabytes)	F: .65	F: .65	F: 3.0	F: .65	F: .65
Data surfaces per spindle	1	1	1	1	1
Track density (TPI)	15875	15875		15875	15875
Maximum linear density (BPI)	27600	27600		27600	27600
PERFORMANCE					
Buffer/cache size (KBytes)	1000	1000		128	128
Average positioning time (msec)					
Average access time (msec)	220	220		80	80
Data transfer rate (MBytes/sec) Internal	3.6*/.6/.3	.6/3.0	1.7/3.5/3.6*	2.7-6.0	3.0-7.2
Data transfer rate (MBytes/sec) External	16.6 PIO Mode 4	16.7			
SIZE (mm: H x W x D)	15 x 129 x 134	12.7 x 128.0 x 129.1		42 x 149 x 196.5	42 x 149 x 196.5
FIRST CUSTOMER SHIPMENT	1Q99	1Q99	3Q99	4Q98	4Q98
COMMENTS	*CD-ROM mode. External slim CD-R.		*CD-ROM mode.		

MANUFACTURER	TATUNG	TATUNG	TEAC	TEAC	TEAC
CD FORMAT DRIVE	DVD-6232E	CRW-4432E	CD-220E	CD-224E	CD-224PE CD-224PEK
DISK/TREND GROUP	21	22	20	20	20
MARKET	DIST	DIST	OEM	OEM	OEM
MEDIA: Recording technology	Replication	Replication	Replication	Replication	Replication
DRIVE: Drive type	DVD-ROM	CD-RW	CD-ROM	CD-ROM	CD-ROM
Relative speed: Read	6.2X, 32X*	32X	8X-20X	24X	24X
Relative speed: Write	--	4X	--	--	
Rotational speed (RPM)			4000	5136	
Interface	IDE/ATAPI	IDE/ATAPI	IDE/ATAPI	IDE/ATAPI	USB/PC Card
Disk insertion	Tray	Tray	Tray	Tray	Top Loading
Speed control	CAV	CAV	CAV	CAV	CAV
CAPACITY/RECORDING DENSITY					
Nominal capacity (Gigabytes)	F: 4.7/8.5	F: .65	F: .65	F: .65	F: .65
Data surfaces per spindle	1, 2	1	1	1	1
Track density (TPI)	34324	15875	15875	15875	15875
Maximum linear density (BPI)	96000	27600	27600	27600	27600
PERFORMANCE					
Buffer/cache size (KBytes)	512	1000	128	128	128
Average positioning time (msec)					
Average access time (msec)	140/95*	120	180	130	130
Data transfer rate (MBytes/sec) Internal External	8.58/4.8*	.6/4.8	1.2-3.0	3.6 16.6 PIO Mode 4	3.6
SIZE (mm: H x W x D)	41.3 x 146 x 195	41.5 x 146 x 210	12.7 x 128 x 130	12.7 x 128 x 129	15 x 130 x 146
FIRST CUSTOMER SHIPMENT	3Q99	3Q99	6/97	4Q97	1Q99
COMMENTS	Purchased mechanism. *CD-ROM mode.	Purchased mechanism.	For Notebook.	For Notebook.	Portable.

MANUFACTURER	TEAC	TEAC	TEAC	TEAC	TEAC
CD FORMAT DRIVE	CD-320E	CD-524E CD-524EA	CD-532E	CD-532S	CD-540E
DISK/TREND GROUP	20	20	20	20	20
MARKET	OEM	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST
MEDIA: Recording technology	Replication	Replication	Replication	Replication	Replication
DRIVE: Drive type	CD-ROM	CD-ROM	CD-ROM	CD-ROM	CD-ROM
Relative speed: Read	8X-20X	12X-24X	13.8X-32X	13.8X-32X	40X max.
Relative speed: Write	--	--	--	--	--
Rotational speed (RPM)	4000	6360-4800	6850	6850	
Interface	IDE/ATAPI	IDE/ATAPI	IDE/ATAPI	Ultra SCSI	IDE/ATAPI
Disk insertion	Tray	Tray	Tray	Tray	Tray
Speed control	CAV	CAV/CLV	CAV	CAV	CAV
CAPACITY/RECORDING DENSITY					
Nominal capacity (Gigabytes)	F: .65	F: .65	F: .65	F: .65	F: .65
Data surfaces per spindle	1	1	1	1	1
Track density (TPI)	15875	15875	15875	15875	15875
Maximum linear density (BPI)	27600	27600	27600	27600	27600
PERFORMANCE					
Buffer/cache size (KBytes)	128	128	128	256	128
Average positioning time (msec)					
Average access time (msec)		90	85	85	85
Data transfer rate (MBytes/sec) Internal	1.2-3.0	1.8-3.6	2.07-4.8	2.07-4.8	6.0 max.
External			16.7 PIO Mode 4	20.0 synch.	
SIZE (mm: H x W x D)	13.7 x 131 x 140.5	41.3 x 146 x 192	41.3 x 146 x 192	41.3 x 146 x 192	41.3 x 146 x 192
FIRST CUSTOMER SHIPMENT	3Q97	6/97	4Q97	4Q97	9/99
COMMENTS	For Notebook.	For Desktop.			MultiRead.

MANUFACTURER	TEAC	TEAC	TEAC	TEAC	TEAC
CD FORMAT DRIVE	DV-22E	DV-25E	CD-R56S-600	CD-R58S CD-RE58S	CD-W54E
DISK/TREND GROUP	21	21	22	22	22
MARKET	OEM	OEM	OEM, DIST	OEM, DIST	OEM, DIST
MEDIA: Recording technology	Replication	Replication	Phase Change	Dye Polymer	Phase Change
DRIVE: Drive type	DVD-ROM	DVD-ROM	CD-R	CD-R	CD-RW
Relative speed: Read	2X/8X-20X*	5X/8X-20X*	24X	24X max.	32X max.
Relative speed: Write	--		6X	8X	4X
Rotational speed (RPM)	1148-3000		5100		
Interface	IDE/ATAPI	IDE/ATAPI	SCSI-2	SCSI-2	
Disk insertion	Tray	Tray	Tray	Tray	
Speed control	CAV/CLV	CAV/CLV	CAV/CLV	CLV/CAV	CLV/CAV
CAPACITY/RECORDING DENSITY					
Nominal capacity (Gigabytes)	F: 4.7/8.75	F: 4.7/8.75	F: .65	F: .65	F: .65
Data surfaces per spindle	1	1	1	1	1
Track density (TPI)	34324	34324	15875	15875	15875
Maximum linear density (BPI)	96000	96000	27600	27600	27600
PERFORMANCE					
Buffer/cache size (KBytes)	512	512	2000	4000	2000
Average positioning time (msec)					
Average access time (msec)	180/150*		150	150	100
Data transfer rate (MBytes/sec) Internal	2.7/1.3-3.0*	6.8/1.3-3.0*	3.6/.9	1.2/3.6	.6/4.8 max.
External	16.6 PIO Mode 4	16.6 PIO Mode 4	10.0 synch.		
SIZE (mm: H x W x D)	12.7 x 129 x 129	12.7 x 129 x 129	41.3 x 146.1 x 192	41.3 x 146.1 x 192	41.3 x 146 x 192
FIRST CUSTOMER SHIPMENT	3Q98	3Q98	4Q98	2Q99	9/99
COMMENTS	*CD-ROM mode. MultiRead.	*CD-ROM mode. MultiRead.		CD-RE58S is external mount.	

MANUFACTURER	TOSHIBA	TOSHIBA	TOSHIBA	TOSHIBA	TOSHIBA
CD FORMAT DRIVE	XM-1602B	XM-1702B	XM-1802B	XM-1902B	XM-6102
DISK/TREND GROUP	20	20	20	20	20
MARKET	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST
MEDIA: Recording technology	Replication	Replication	Replication	Replication	Replication
DRIVE: Drive type	CD-ROM	CD-ROM	CD-ROM	CD-ROM	CD-ROM
Relative speed: Read	8.5X-20X	10.3X-24X	10.3X-24X	10.3X-24X	24X
Relative speed: Write	--	--	--	--	--
Rotational speed (RPM)	4505-2400	5200	5200	5200	6360-3200
Interface	IDE/ATAPI	IDE/ATAPI	IDE/ATAPI	IDE/ATAPI	IDE/ATAPI
Disk insertion	Tray	Tray	Tray	Tray	Tray
Speed control	CAV/CLV	CAV	CAV	CAV	CAV
CAPACITY/RECORDING DENSITY					
Nominal capacity (Gigabytes)	F: .65	F: .65	F: .65	F: .65	F: .65
Data surfaces per spindle	1	1	1	1	1
Track density (TPI)	15875	15875	15875	15875	15875
Maximum linear density (BPI)	25400	27600	25400	27600	25400
PERFORMANCE					
Buffer/cache size (KBytes)	128	128	128	128	256
Average positioning time (msec)	125	100	100	90	85
Average access time (msec)	135	110	110	99	90
Data transfer rate (MBytes/sec) Internal	1.28-3.0	1.545-3.6	1.545-3.6	1.545-3.6	3.6
External	11.1 PIO Mode 3	16.7 PIO Mode 4	16.7 PIO Mode 4	33.3 Ultra DMA	13.3 PIO Mode 3
SIZE (mm: H x W x D)	12.7 x 128 x 129	12.7 x 128 x 129	12.7 x 128 x 129	12.7 x 128 x 129	41.1 x 144.5 x 188.2
FIRST CUSTOMER SHIPMENT	2Q97	4Q97	Q298	Q199	2Q97
COMMENTS			MultiRead.		MultiRead.

MANUFACTURER	TOSHIBA	TOSHIBA	TOSHIBA	TOSHIBA	TOSHIBA
CD FORMAT DRIVE	XM-6201B XM-6201F1	XM-6202B	XM-6202S	XM-6302B	XM-6401B
DISK/TREND GROUP	20	20	20	20	20
MARKET	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST
MEDIA: Recording technology	Replication	Replication	Replication	Replication	Replication
DRIVE: Drive type	CD-ROM	CD-ROM	CD-ROM	CD-ROM	CD-ROM
Relative speed: Read	13.8X-32X	13.8X-32X	13.8X-32X	13.8X-32X	17.3X-40X
Relative speed: Write	--	--	--	--	--
Rotational speed (RPM)	6900	6900	6900	6900	8500
Interface	SCSI-2	IDE/ATAPI	IDE/ATAPI	IDE/ATAPI	Ultra SCSI
Disk insertion	Tray	Tray	Slot	Tray	Tray
Speed control	CAV	CAV	CAV	CAV	CAV
CAPACITY/RECORDING DENSITY					
Nominal capacity (Gigabytes)	F: .65	F: .65	F: .65	F: .65	F: .65
Data surfaces per spindle	1	1	1	1	1
Track density (TPI)	15875	15875	15875	15875	15875
Maximum linear density (BPI)	27600	27600	27600	25400	27600
PERFORMANCE					
Buffer/cache size (KBytes)	256	256	256	256	256
Average positioning time (msec)	85	78	78	80	75
Average access time (msec)	90	83	83	85	80
Data transfer rate (MBytes/sec) Internal External	2.07-4.8 10.0 synch.	2.07-4.8 16.7 PIO Mode 4	2.07-4.8 16.7 PIO Mode 4	2.07-4.8 16.7 PIO Mode 4	2.6-6.0 20 synch.
SIZE (mm: H x W x D)	41.5 x 146 x 193	41.5 x 148 x 193	41.5 x 146 x 190	41.5 x 146 x 193	41.5 x 146 x 193
FIRST CUSTOMER SHIPMENT	4Q97	4Q97	4Q97	1Q98	Q498
COMMENTS	F1 model is external mount. MultiRead.	MultiRead.	MultiRead.	MultiRead.	MultiRead.

MANUFACTURER	TOSHIBA	TOSHIBA	TOSHIBA	TOSHIBA	TOSHIBA
CD FORMAT DRIVE	XM-6402B	XM-6502B	SD-C2002	SD-C2102	SD-C2202
DISK/TREND GROUP	20	20	21	21	21
MARKET	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST
MEDIA: Recording technology	Replication	Replication	Phase Change	Replication	Replication
DRIVE: Drive type	CD-ROM	CD-ROM	DVD-ROM	DVD-ROM	DVD-ROM
Relative speed: Read	13.8X-32X	17.3X-40X	2X/16X*	2.4X/20X*	4X/32X*
Relative speed: Write	--	--	--	--	--
Rotational speed (RPM)	6900	8500			
Interface	IDE/ATAPI	IDE/ATAPI	IDE/ATAPI	IDE/ATAPI	IDE/ATAPI
Disk insertion	Tray	Tray	Tray	Tray	Tray
Speed control	CAV	CAV	CLV	CLV/CAV	CAV
CAPACITY/RECORDING DENSITY					
Nominal capacity (Gigabytes)	F: .65	F: .65	F: 4.700/8.750	F: 4.7/8.5/.65*	F: 4.7/8.5
Data surfaces per spindle	1	1	1, 2	1, 2	1
Track density (TPI)	15875	15875	34324	34324	34324
Maximum linear density (BPI)	27600	27600	96000	96000	96000
PERFORMANCE					
Buffer/cache size (KBytes)	128	128		128	128
Average positioning time (msec)	80	75	110/110*	140/105*	160
Average access time (msec)	85	80	180/120	160/110*	
Data transfer rate (MBytes/sec) Internal	2.07-4.8	2.6-6.0	2.7/2.4*	3.268/3.0*	5.4/3.6*
External	33.3 Ultra DMA	33.3 Ultra DMA	16.7 PIO Mode 4	16.7 PIO Mode 4	
SIZE (mm: H x W x D)	41.5 x 146 x 193	41.5 x 146 x 193	17 x 133.1 x 128	12.7 x 128 x 129	12.7 x 128 x 129
FIRST CUSTOMER SHIPMENT	4Q98	1Q99	4Q97	6/98	1998
COMMENTS		MultiRead.	*CD-ROM mode.	*CD-ROM mode.	*CD-ROM mode. MultiRead.

MANUFACTURER	TOSHIBA	TOSHIBA	TOSHIBA	TOSHIBA	TOSHIBA
CD FORMAT DRIVE	SD-M1201	SD-M1202	SD-M1212	SD-W1001	SD-W1002
DISK/TREND GROUP	21	21	21	22	22
MARKET	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST
MEDIA: Recording technology	Replication	Replication	Replication	Phase Change	Phase Change
DRIVE: Drive type	DVD-ROM	DVD-ROM	DVD-ROM	DVD-RAM	DVD-RAM
Relative speed: Read	2.1X-5X/32X*	2X-4.8X/32X*	2.5X-6X/32X*	1X/16X*	1X/16X*
Relative speed: Write	--	--	--	1X	1X
Rotational speed (RPM)	2900/6900*	2800/6900*	3500/6900*		
Interface	Ultra SCSI	IDE/ATAPI	IDE/ATAPI	SCSI-2	IDE/ATAPI
Disk insertion	Tray	Tray	Tray	Tray	Tray
Speed control	CAV	CAV	CAV	ZCAV	ZCAV
CAPACITY/RECORDING DENSITY					
Nominal capacity (Gigabytes)	F: 4.7/8.5/.65*	F: 4.7/8.5/.65*	F: 4.7/8.5/.65*	F: 2.6	F: 2.6
Data surfaces per spindle	1, 2	1, 2	1, 2	1	1
Track density (TPI)	34324	34324	34324	34324	34324
Maximum linear density (BPI)	96000	96000	96000	62000	62000
PERFORMANCE					
Buffer/cache size (KBytes)	256	256	256	256	256
Average positioning time (msec)	105/90*	105/90*	90/80*	150/130*	150/130*
Average access time (msec)	135/95*	135/95*	110/85*		
Data transfer rate (MBytes/sec) Internal	2.8-6.76/4.8*	2.7-6.535/4.8*	8.11/4.8*	1.35/2.4*	1.35/2.4*
External	20 synch.	16.7 PIO Mode 4	16.7/33.3 UDMA	10.0	16.7 PIO Mode 4
SIZE (mm: H x W x D)	41.5 x 146 x 193	41.5 x 146 x 193	41.5 x 146 x 193	41.3 x 146 x 203	41.3 x 146 x 203
FIRST CUSTOMER SHIPMENT	1Q99	6/98	1Q99	1Q98	1Q98
COMMENTS	*CD-ROM mode. MultiRead.	*CD-ROM mode.	*CD-ROM mode. MultiRead.	*CD-ROM mode.	*CD-ROM mode.

MANUFACTURER	TOSHIBA	TOSHIBA	ULTIMA ELECTRONICS (ARTEC)	ULTIMA ELECTRONICS (ARTEC)	ULTIMA ELECTRONICS (ARTEC)
CD FORMAT DRIVE	SD-W1101	SD-W1111	Super-40X	Super-44X	Super-48X
DISK/TREND GROUP	22	22	20	20	20
MARKET	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST
MEDIA: Recording technology	Phase Change	Phase Change	Replication	Replication	Replication
DRIVE: Drive type	DVD-RAM	DVD-RAM	CD-ROM	CD-ROM	CD-ROM
Relative speed: Read	2X/6.6X-16X*	2X/16X*	17.2X-40X	19.1X-44X	20.7X-48X
Relative speed: Write	1X	1X	--	--	
Rotational speed (RPM)	2400/2800/3516*	2400/2800/3516*	8000	8800	9600
Interface	SCSI-2	SCSI-2	IDE/ATAPI	IDE/ATAPI	IDE/ATAPI
Disk insertion	Tray, Caddy	Tray	Tray	Tray	Tray
Speed control	ZCAV	ZCAV	CAV	CAV	CAV
CAPACITY/RECORDING DENSITY					
Nominal capacity (Gigabytes)	F: 2.6	F: 2.6	F: .65	F: .65	F: .65
Data surfaces per spindle	1	1	1	1	1
Track density (TPI)	34324	34324	15875	15875	15875
Maximum linear density (BPI)	62000	62000	27600	27600	27600
PERFORMANCE					
Buffer/cache size (KBytes)	256	2000	128	128	128
Average positioning time (msec)	180/260/150*	180			
Average access time (msec)	120/210/140*		100	100	100
Data transfer rate (MBytes/sec) Internal	1.37/2.7/2.4	1.37/2.7/2.4*	2.58-6.0	2.87-6.6	3.1-7.2
External	10.0 synch.	20 synch.			PIO Mode 4
SIZE (mm: H x W x D)	41.3 x 146 x 203	41.3 x 146 x 203	43 x 149 x 196	43 x 149 x 196	43 x 149 x 146
FIRST CUSTOMER SHIPMENT	2Q98	3Q99	1998	1998	1998
COMMENTS	*CD-ROM mode. RPM is max. rating.	*CD-ROM mode.			

MANUFACTURER	ULTIMA ELECTRONICS (ARTEC)	ULTIMA ELECTRONICS (ARTEC)	WEARNES PERIPHERALS	WEARNES PERIPHERALS	WEARNES PERIPHERALS
CD FORMAT DRIVE	Super-50X	Super-RW	CDS-32x Max	CDS-36x Max	CDRW-1622
DISK/TREND GROUP	20	22	20	20	22
MARKET	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST
MEDIA: Recording technology	Replication	Phase Change	Replication	Replication	Phase Change
DRIVE: Drive type	CD-ROM	CD-RW	CD-ROM	CD-ROM	CD-RW
Relative speed: Read	21.7X-50X		14X-32X	36X max.	16X
Relative speed: Write	--		--	--	2X
Rotational speed (RPM)	10000		7420-6400		
Interface	IDE/ATAPI	IDE/ATAPI	IDE/ATAPI	IDE/ATAPI	IDE/ATAPI
Disk insertion	Tray	Tray	Tray	Tray	Tray
Speed control	CAV	CLV	CAV/CLV	CAV	CLV/CAV*
CAPACITY/RECORDING DENSITY					
Nominal capacity (Gigabytes)	F: .65	F: .65	F: .65	F: .65	F: .65
Data surfaces per spindle	1	1	1	1	1
Track density (TPI)	15875	15875	15875	15875	15875
Maximum linear density (BPI)	27600	27600	27600	27600	27600
PERFORMANCE					
Buffer/cache size (KBytes)	128		128/256	128/256	1000
Average positioning time (msec)					
Average access time (msec)	100		100		
Data transfer rate (MBytes/sec) Internal	3.26-7.5		2.1-4.8	2.3-5.4	2.4 RD/.3 WR
External			16.7 PIO Mode 4	16.6 PIO Mode 4	
SIZE (mm: H x W x D)	43 x 149 x 196		42.9 x 149 x 208	42.9 x 149 x 208	
FIRST CUSTOMER SHIPMENT	1998	2Q98	4Q97		
COMMENTS			MultiRead.		*CD-ROM mode.

MANUFACTURER	WEARNES PERIPHERALS	WEARNES PERIPHERALS	WEARNES PERIPHERALS	WEARNES PERIPHERALS	WEARNES PERIPHERALS
CD FORMAT DRIVE	CDRW-1688	CDRW-1688S	CDRW-2422	CDRW-2444	CDRW-44X
DISK/TREND GROUP	22	22	22	22	22
MARKET	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST
MEDIA: Recording technology	Phase Change	Phase Change	Phase Change	Phase Change	Phase Change
DRIVE: Drive type	CD-RW	CD-RW	CD-RW	CD-RW	CD-RW
Relative speed: Read	16X	16X	24X max.	24X max.	24X max.
Relative speed: Write	4X	4X	2X	4X	4X
Rotational speed (RPM)					
Interface	IDE/ATAPI	SCSI-2	IDE/ATAPI	IDE/ATAPI	PCMCIA/USB/1394
Disk insertion	Tray	Tray	Tray	Tray	Top Loading
Speed control	CLV/CAV*	CLV/CAV*	CLV/CAV*	CLV/CAV*	CLV/CAV*
CAPACITY/RECORDING DENSITY					
Nominal capacity (Gigabytes)	F: .65	F: .65	F: .65	F: .65	F: .65
Data surfaces per spindle	1	1	1	1	1
Track density (TPI)	15875	15875	15875	15875	15875
Maximum linear density (BPI)	27600	27600	27600	27600	27600
PERFORMANCE					
Buffer/cache size (KBytes)			1000	1000	1000
Average positioning time (msec)					
Average access time (msec)			135	135*	135*
Data transfer rate (MBytes/sec) Internal External	2.4 RD/.6 WR	2.4 RD/.6 WR	.3/3.6*	.6/3.6*	.6/3.6*
SIZE (mm: H x W x D)				42.2 x 148.6 x 210	
FIRST CUSTOMER SHIPMENT	2Q99	1Q99	2Q99	3Q99	3Q99
COMMENTS	*CD-ROM mode.	*CD-ROM mode.	*CD-ROM mode.	*CD-ROM mode.	*CD-ROM mode.

MANUFACTURER	WEARNES PERIPHERALS	WEARNES PERIPHERALS	YAMAHA	YAMAHA	YAMAHA
CD FORMAT DRIVE	CDRW-622	CDRW-642	CRW4416E	CRW4416S CRW4416Sx	CRW6416S
DISK/TREND GROUP	22	22	22	22	22
MARKET	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST
MEDIA: Recording technology	Phase Change	Phase Change	Phase Change	Phase Change	Phase Change
DRIVE: Drive type	CD-RW	CD-RW	CD-RW	CD-RW	CD-RW
Relative speed: Read	6X	6X	16X	16X	9X-16X
Relative speed: Write	2X	4X CDR,2X CDRW	4X	4X	6X R/4X RW
Rotational speed (RPM)	3180-400		5300-400	5300-400	
Interface	IDE/ATAPI	IDE/ATAPI	IDE/ATAPI	SCSI-2	SCSI-2
Disk insertion	Tray	Tray	Tray	Tray	Tray
Speed control	CLV	CLV	CLV/CAV	CLV/CAV	CLV/CAV
CAPACITY/RECORDING DENSITY					
Nominal capacity (Gigabytes)	F: .65	F: .65	.666 Mode 2 F: .540 Mode 1	.666 Mode 2 F: .540 Mode 1	.666 Mode 2 F: .540 Mode 1
Data surfaces per spindle	1	1	1	1	1
Track density (TPI)	15875	15875	15875	15875	15875
Maximum linear density (BPI)	27600	27600	27600	27600	27600
PERFORMANCE					
Buffer/cache size (KBytes)		2000	2000	2000	2000
Average positioning time (msec)			160	160	160
Average access time (msec)			180	180	180
Data transfer rate (MBytes/sec) Internal External	.3WR/.9 RD	.9 RD,.6/.3 WR	2.4 max. 13.1 PIO Mode 3	2.4 max. 8.0 synch.	1.35-2.4/.9/.6 10.0 synch.
SIZE (mm: H x W x D)	42 x 149 x 210.5		41.3 x 146 x 193.1	41.3 x 146 x 193.1	41.3 x 146 x 193.1
FIRST CUSTOMER SHIPMENT	4Q97		9/98	9/98	1Q99
COMMENTS	UDF packet writing.		UDF packet writing.	Sx is external mount. UDF packet writing.	UDF packet writing.

READ/WRITE OPTICAL DISK DRIVE SPECIFICATIONS

OPTICAL DISK DRIVE SPECIFICATIONS

Coverage: The following pages list optical disk drives (excluding CD format drives, which are covered in another section) intended for computer data storage which are now announced or in new production. In a few cases, products are listed for which only preliminary announcements have been made because they are judged to be significant indicators of industry direction in the production period shown.

Recording technology: The type of recording layer is indicated (magneto-optic, phase change, dye-polymer, etc.).

Operating mode: Drive operating mode is indicated as write once, rewritable or multifunction. Rewritable drives use magneto-optic technology unless otherwise indicated. Drives characterized as "Multifunction" can work with write-once or rewritable media. Where the drive is a magneto-optic type and supports multi-functionality using MO-WORM (CCW) media, "Multifunction-(MO)" is used.

Interface: Specific interfaces are listed for most of the drives. The abbreviation "HPAC" means an auxiliary interface channel for use with Hewlett-Packard auto-changers or compatible equipment is provided.

Speed control: The following abbreviations are used:

CAV = constant angular velocity.

CLV = constant linear velocity.

ZCAV = zoned constant angular velocity.

Capacities: Capacities are listed as "F" for formatted. For optical drives that can access only one side of the media, drives are categorized in terms of one side capacity, even if the drive uses two-sided media. As optical media is pre-formatted, the capacity given is the formatted capacity. Track capacity in CLV and ZCAV drives is variable, so this parameter is given only for CAV drives.

Rotational speed: If more than one speed range exists, as for CD-ROM drives, only the highest performance range is given.

Servo type: Optical drive servo types are noted as:

Continuous: Continuous composite servo format.

Sampled: Sampled servo format.

Average access time: The average access time is the sum of average positioning time plus rotational latency. Optical drive manufacturers are inconsistent in the use of this definition, so while the values given for these specifications are believed to be accurate, they should be accepted with caution and individual drive manufacturers contacted for details.

Spin-up/spin-down time: The time for the disk to accelerate to operating speed after insertion/time to decelerate to a stop so that the disk can be removed.

Data transfer rate: The data transfer rate given is the rate from the disk during reading. When more than one rate is given:

If separated by a hyphen, the figures represent the drive's minimum and maximum transfer rates.

If separated by a slash, the figures represent the rates obtained when the drive operates at more than one RPM or offers more than one capacity.

Accuracy: All of the information in this section has been checked for accuracy. Due to rapid changes in the industry, report users may need to make verbal inquiries of manufacturers for updates. Where data is not specified or otherwise unavailable, the abbreviation "NS" is used. Where a specification is not applicable, the abbreviation "N/A" appears.

1999 DISK/TREND Optical and Removable Disk Drive product groups

Group number	Drives included
CD format optical disk drives	
20:	CD format read-only optical disk drives.
21:	DVD format read-only optical disk drives.
22:	CD/DVD format writable optical disk drives.
Read/write optical disk drives	
23	Read/Write optical disk drives, less than 4 gigabytes.
24	Read/Write optical disk drives, more than 4 gigabytes.
Removable rigid disk drives	
1	Rigid disk cartridge drives.
2	Card format rigid disk drives.
Flexible disk drives	
13	High capacity flexible disk drives.
14	Low capacity flexible disk drives.

MANUFACTURER	FUJITSU	FUJITSU	FUJITSU	FUJITSU	FUJITSU
OPTICAL DRIVE	DynaMO 640 PC	DynaMO 640Si	DynaMo 640AI	DynaMo 640SE	DynaMo 640SZI
DISK/TREND GROUP	23	23	23	23	23
MARKET	DIST	OEM	DIST	DIST	DIST
MEDIA: Disk diameter	86 mm	86 mm	86 mm	86 mm	86 mm
Recording technology	Magneto-Optic	Magneto-Optic	Magneto-Optic	Magneto-Optic	Magneto-Optic
DRIVE: Operating mode	Rewritable	Rewritable	Rewritable	Rewritable	Rewritable
Direct overwrite	Yes	Yes	Yes	Yes	Yes
Interface	SCSI-2	SCSI-2	IDE/ATAPI	SCSI-2	SCSI-2
Speed control	ZCAV	ZCAV	ZCAV/CAV*	ZCAV/CAV*	ZCAV/CAV*
CAPACITY/RECORDING DENSITY					
On-line capacity (Gigabytes)	F: .540/.640	F: .540/.640	F: .540/.640	F: .540/.640	F: .540/.640
Capacity per disk (Gigabytes)	F: .540/.640	F: .540/.640	F: .540/.640	F: .540/.640	F: .540/.640
Data surfaces per spindle	1	1	1	1	1
Tracks per surface	18480/42042	18316	18480	18480	18480
Track density (TPI)	23090	23000	23090	23090	23090
Maximum linear density (BPI)	52900	53000	52900	52900	52900
Rotational speed (RPM)	3600	3600	3600	3600	3600
PERFORMANCE					
Buffer/cache size (Kbytes)	2000	2000	2000	2000	2000
Servo type	Continuous	Continuous	Continuous	Continuous	Continuous
Average positioning time (msec)	35	35	28	28	28
Average rotational delay (msec)	8.3	8.3	8.3	8.3	8.3
Average access time (msec)	43.3	43.3	38.3	38.3	38.3
Spin-up/Spin-down times (sec)	7/4	7/4	7/5	7/5	7/5
Data transfer rate (MBytes/sec) Internal	2.3-3.9	2.3-3.9	3.9 max.	3.9 max.	3.9 max.
External	10.0 synch.	10.0 synch.	16.6 PIO Mode 4	10.0 synch.	10.0 synch.
SIZE (mm: H x W x D)	55 x 170 x 225	25.4 x 101.6 x 160	23.4 x 101.6 x 160	45 x 126 x 215	25.4 x 101.6 x 160
FIRST CUSTOMER SHIPMENT	4Q96	6/97	7/98	6/98	6/98
COMMENTS	External mount.		*Read/Write 128 + 230 MB media.	*Read/Write 128 + 230 MB media. External mount.	*Read/Write 128 + 230 MB media.

MANUFACTURER	FUJITSU	FUJITSU	FUJITSU	FUJITSU	FUJITSU
OPTICAL DRIVE	M2513A Cat-4	M2541B DynaMO 230 Portable	M2541BD MicroCat-3	MCB3064SS	MCC3064AP
DISK/TREND GROUP	23	23	23	23	23
MARKET	OEM, DIST	OEM, DIST	OEM, DIST	OEM	OEM
MEDIA: Disk diameter	86 mm	86 mm	86 mm	86 mm	86 mm
Recording technology	Magneto-Optic	Magneto-Optic	Magneto-Optic	Magneto-Optic	Magneto-Optic
DRIVE: Operating mode	Rewritable	Rewritable	Rewritable	Rewritable	Rewritable
Direct overwrite	Yes	Yes		Yes	
Interface	SCSI-2	IDE	IDE	SCSI-2	IDE/ATAPI
Speed control	ZCAV	CAV/ZCAV	CAV/ZCAV	CAV/ZCAV	CAV/ZCAV
CAPACITY/RECORDING DENSITY					
On-line capacity (Gigabytes) Capacity per disk (Gigabytes)	F: .540/.640 F: .540/.640	F: .128/.230 F: .128/.230	F: .128/.230 F: .128/.230	F: .540/.640 F: .540/.640	F: .540/.640 F: .540/.640
Data surfaces per spindle	1	1	1	1	1
Tracks per surface	18480/42042	10000/17940	10000/17940	18480/42042	18480/42042
Track density (TPI)	23090	15875/18275	15875/18275	23090	23090
Maximum linear density (BPI)	52900	24400/29300	24400/29300*	52900*	52900*
Rotational speed (RPM)	3600	2700	2700	4300	3600
PERFORMANCE					
Buffer/cache size (Kbytes)	2000/512	128	128	2000	512
Servo type	Continuous	Continuous	Continuous	Continuous	Continuous
Average positioning time (msec)	30	70	70	28	28
Average rotational delay (msec)	8.3	11	11.1	7	8.3
Average access time (msec)	38.3	81	81.1	35	38.3
Spin-up/Spin-down times (sec)	7/4	7/6	7/6	7/5	7/5
Data transfer rate (MBytes/sec) Internal External	2.3-3.9 5.0/10.0 synch.	.975-1.575 6.0/8.0	1.0-1.6 6.0/8.0	4.7 max. 10.0 synch.	3.9 10.0 synch.
SIZE (mm: H x W x D)	25.4 x 101.6 x 146	17 x 101.6 x 140	17.2 x 101.6 x 140	25.4 x 101.6 x 146	25.4 x 101.6 x 146
FIRST CUSTOMER SHIPMENT	4/96	10/95	1996	4Q97	4Q97
COMMENTS		DynaMO is external subsystem.	*2,7 RLL Code.	Read/Write compatible with 128/230 MB media. *1,7 RLL Code.	Read/Write compatible with 128/230 MB media. *1,7 RLL Code.

MANUFACTURER	FUJITSU	FUJITSU	FUJITSU	HITACHI	HITACHI
OPTICAL DRIVE	MCC3064SS	MCC3064XX	ZEBO	OD172 OU172	OL-F172S/D-21
DISK/TREND GROUP	23	23	23	23	23
MARKET	OEM	DIST	DIST	CAPT,OEM,DIST	Captive
MEDIA: Disk diameter	86 mm	86 mm	86 mm	130 mm	130 mm
Recording technology	Magneto-Optic	Magneto-Optic	Magneto-Optic	Magneto-Optic	Magneto-Optic
DRIVE: Operating mode	Rewritable	Rewritable	Rewritable	Multifunct-(MO)	Multifunct-(MO)
Direct overwrite	Yes	Yes	Yes	Yes	Yes
Interface	SCSI-2	SCSI-2	SCSI-2	SCSI-2	SCSI-2
Speed control	CAV/ZCAV	CAV/ZCAV	ZCAV	ZCAV	ZCAV
CAPACITY/RECORDING DENSITY					
On-line capacity (Gigabytes)	F: .540/.640	F: .540/.640	F: .540/.640	F: 1.304	F: 1.304
Capacity per disk (Gigabytes)	F: .540/.640	F: .540/.640	F: .540/.640	F: 2.607	F: 2.607
Data surfaces per spindle	1	1	1	1	1
Tracks per surface	18480/42042	18480	18480/42042	74883 (logical)	74883 (logical)
Track density (TPI)	23090	23090	23090	23000	23000
Maximum linear density (BPI)	52900*	52900*	52900	50000*	50000*
Rotational speed (RPM)	3600	3600	3600	3000	3000
PERFORMANCE					
Buffer/cache size (Kbytes)	2000	2000	2000	1000	1000
Servo type	Continuous	Continuous	Continuous	Continuous	Continuous
Average positioning time (msec)	28	28	35	39	39
Average rotational delay (msec)	8.3	8.3	8.3	10	10
Average access time (msec)	36.3	38.3	43.3	49	49
Spin-up/Spin-down times (sec)	7/5	7/5	7/4	7.5/4.5	5.0/2.5
Data transfer rate (MBytes/sec) Internal	3.87 max.	3.9 max.	3.9	2.3-4.6	2.3-4.6
External	10.0 synch.	10.0 synch.	10.0 synch.	10.0 synch.	10.0 synch.
SIZE (mm: H x W x D)	25.4 x 101.6 x 146	25.4 x 101.6 x 160	116 x 60 x 200	41.3 x 146 x 203.7	82.5 x 146 x 203.2
FIRST CUSTOMER SHIPMENT	4Q97	5/98	1997	4Q95	1Q96
COMMENTS	Read/Write compatible with 128/230 MB media. *1,7 RLL Code.	Read/Write compatible with 128/230 MB media. *1,7 RLL Code.	External mount. Sold in Japan.	*1,7 RLL Code. OU is external mount.	*1,7 RLL Code.

MANUFACTURER	KONICA	KONICA	MAXOPTIX	MAXOPTIX	MOUNTAIN OPTECH
OPTICAL DRIVE	OMD-9060	OMD-9062	T5-2600	T6-5200	ST-5200 CS-5200
DISK/TREND GROUP	23	23	23	23	23
MARKET	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST	OEM
MEDIA: Disk diameter	86 mm	86 mm	130 mm	130 mm	130 mm
Recording technology	Magneto-Optic	Magneto-Optic	Magneto-Optic	Magneto-Optic	Magneto-Optic
DRIVE: Operating mode	Rewritable	Rewritable	Multifunct-(MO)	Multifunct-(MO)	Rewritable
Direct overwrite	Yes	Yes		Yes	
Interface	SCSI-2	SCSI-2	SCSI-2	Ultra SCSI	SCSI-2
Speed control	CAV	CAV	CAV	ZCAV	ZCAV
CAPACITY/RECORDING DENSITY					
On-line capacity (Gigabytes)	F: .640	F: .640	F: .32/.65/1.30	.32/.65/1.3/2.6	F: 2.6
Capacity per disk (Gigabytes)	F: .640	F: .640	F:.64/1.30/2.61	.65/1.3/2.6/5.2	F: 5.2
Data surfaces per spindle	1	1	1	1	1
Tracks per surface	42042	42042	26010*	35294	35294
Track density (TPI)	23090	23090	22100	29780	29780
Maximum linear density (BPI)	52900	52900	51000	63140	63140
Rotational speed (RPM)	4500	5150*/4500	3868	2942	2942
PERFORMANCE					
Buffer/cache size (Kbytes)	2000	2000	1024	4000, 8000	4000
Servo type	Continuous	Continuous	Continuous	Continuous	Continuous
Average positioning time (msec)	21.3	22.2*/21.3	20	20	20
Average rotational delay (msec)	6.7	5.8*/6.7	7.7	10.2	10
Average access time (msec)	28	28	27.7	30.2	30
Spin-up/Spin-down times (sec)			4.5/2.5	3.5/1.9	3.5/1.9
Data transfer rate (MBytes/sec) Internal	1.9-3.8	1.9-3.8	4.6	2.85 - 5.9	2.85-5.9
External			10.0 synch.	20 synch.	20 synch.
SIZE (mm: H x W x D)	25.4 x 101.6 x 146	25.4 x 101.6 x 146	41.3 x 146 x 203	41.3 x 146.1 x 203.2	45.8 x 146.1 x 203.2
FIRST CUSTOMER SHIPMENT	2Q98	2/99	2Q97	8/98	1998
COMMENTS		*With 230 MB media.	*75735 logical tracks.		Ruggedized. CS-5200 is commercial version.

MANUFACTURER	NEC	NEC	NEW ATG	NEW ATG	NEW ATG
OPTICAL DRIVE	N1137-57 N7915-85 ODD-155 PC-OD502	ODD-160	GD 6001	GD 9001/SE	VFD 16000
DISK/TREND GROUP	23	23	24	24	24
MARKET	Captive	OEM	OEM	OEM	OEM
MEDIA: Disk diameter	130 mm	130 mm	300 mm	300 mm	300 mm
Recording technology	Magneto-Optic	Magneto-Optic	Ablative	Ablative	Ablative
DRIVE: Operating mode	Rewritable	Rewritable	Write Once	Write Once	Write Once
Direct overwrite	No	Yes	No	No	No
Interface	SCSI	SCSI-2	SCSI	SCSI, SCSI-2	SCSI-2
Speed control	ZCAV	ZCAV	CAV	ZCAV	ZCAV
CAPACITY/RECORDING DENSITY					
On-line capacity (Gigabytes) Capacity per disk (Gigabytes)	F: .65/.325 F: 1.3/.65	F: 1.3 F: 2.6	F: 3.2	F: 5.1	F: 16.0 F: 16.0
Data surfaces per spindle	1	1	1	1	2
Tracks per surface	21600*	2600	62500	82000	86667
Track density (TPI)	18273	21200	25400	25400	28200
Maximum linear density (BPI)	29540	51000	28200	25400	
Rotational speed (RPM)	4200/3000	3000	1143	914	1042
PERFORMANCE					
Buffer/cache size (Kbytes)	1000	4000			
Servo type	Continuous	Continuous	Sampled	Sampled	Sampled
Average positioning time (msec)	32	35	90	90	90
Average rotational delay (msec)	10/7	10	26.2	33	29
Average access time (msec)	42/39	45	116.2	123	119
Spin-up/Spin-down times (sec)		2.5			3.0/1.8
Data transfer rate (MBytes/sec) Internal External	1.94	1.69-3.38	1.0	1.0	3.3 10.0 synch.
SIZE (mm: H x W x D)	41.3 x 146.1 x 203.2	42 x 148 x 295.2	174 x 440 x 530	177 x 482 x 532.5	178 x 430 x 580
FIRST CUSTOMER SHIPMENT	3Q93	1Q96	4Q90	2Q92	3Q96
COMMENTS	*37600 logical tracks. ODD-155 is external pkg. Purchased mechanism.	2 beam head. 1 cycle write.	Differs from GD 6000 in the cartridge (single operation loading).	Can read GD 6000 disks and read/write GD 9001.	Read compatibility for GD 6001.

MANUFACTURER	OLYMPUS	OLYMPUS	OLYMPUS	OLYMPUS	OLYMPUS
OPTICAL DRIVE	MO1300	MOS330E MOS330S MOS331E* MOS331S*	MOS350E	PowerMO 640 640MO Turbo Black/White	SYS.230
DISK/TREND GROUP	23	23	23	23	23
MARKET	OEM, DIST	OEM	OEM	DIST	DIST
MEDIA: Disk diameter	86 mm	86 mm	86 mm	86 mm	86 mm
Recording technology	Magneto-Optic	Magneto-Optic	Magneto-Optic	Magneto-Optic	Magneto-Optic
DRIVE: Operating mode	Rewritable	Rewritable	Rewritable	Rewritable	Rewritable
Direct overwrite	No		Yes	Yes	
Interface	SCSI-2	SCSI-2	SCSI-2	SCSI-2	SCSI-2,Prt.Port
Speed control	CAV	CAV/ZCAV	CAV/ZCAV	CAV/ZCAV	CAV/ZCAV**
CAPACITY/RECORDING DENSITY					
On-line capacity (Gigabytes)	F:.128-.64/1.3*	F: .230/.128	F: .540/.640	F: .540/.640	F: .128/.230
Capacity per disk (Gigabytes)	F:.128-.64/1.3*		F: .540/.640	F: .540/.640	F: .128/.230
Data surfaces per spindle	1	1	1	1	1
Tracks per surface	36855	11500**	18480	18480	11500*
Track density (TPI)	28200	18273	23090	23090	18273
Maximum linear density (BPI)	89100	29300	52900	52900	29300
Rotational speed (RPM)	3214*/4500	4200	4335	4335	4200
PERFORMANCE					
Buffer/cache size (Kbytes)	2000	256, 1000*	2000	2000	256
Servo type	Continuous	Continuous	Continuous	Continuous	Continuous
Average positioning time (msec)		27	27	27	27
Average rotational delay (msec)		7.1	6.9	6.9	7.1
Average access time (msec)	28	34.1	34	34	34.1
Spin-up/Spin-down times (sec)					
Data transfer rate (MBytes/sec) Internal	5.92 max.*	1.075-1.72/.896	.920-3.5	.920-3.5	2.4
External	10.0 synch.	5.0 synch.	6.7	6.7	
SIZE (mm: H x W x D)	43 x 136 x 217	25.4 x 101.6 x 153.5	25.4 x 101.6 x 158	43 x 136 x 217	50.4 x 152.4 x 203.2
FIRST CUSTOMER SHIPMENT	2Q99	2Q96	2Q98	2Q98	
COMMENTS	Preliminary specification. *At 1.3 GB capacity.	*1 MB optional. **37600 logical tracks.		Not sold in US. External mount.	*37600 logical tracks. **At highest capacity. External mount.

MANUFACTURER	PINNACLE MICRO	PINNACLE MICRO	PIONEER	PIONEER	PIONEER
OPTICAL DRIVE	Apex	Ultra 5.2	DE-SH2200 DE-UH2200	DE-SH7101 DE-UH7101	DE-SH9101 DE-UH9101
DISK/TREND GROUP	23	23	23	23	23
MARKET	OEM, DIST	OEM, DIST	OEM, DIST	OEM	OEM, DIST
MEDIA: Disk diameter	130 mm	130 mm	130 mm	130 mm	130 mm
Recording technology	Magneto-Optic	Magneto-Optic	Magneto-Optic	MO/Dye Polymer	MO/Dye Polymer
DRIVE: Operating mode	Multifunct-(MO)	Multifunct-(MO)	Rewritable	Multifunction	Multifunction
Direct overwrite	Yes				
Interface	SCSI-2/HPAC	SCSI-2	SCSI	SCSI	SCSI
Speed control	ZCAV	ZCAV	CAV	CAV	CAV
CAPACITY/RECORDING DENSITY					
On-line capacity (Gigabytes) Capacity per disk (Gigabytes)	F: 1.3/2.286** F: 1.61/4.57**	F: .65/1.3/2.6 F: 1.3/2.6/5.2	F: 1.1 F: 2.2	F: .327 F: . 654	F: .850/.327 F: 1.7/.654
Data surfaces per spindle	1	1	1	1	1
Tracks per surface	36300 (user)	35294		19958	
Track density (TPI)	25400	29780		15875	
Maximum linear density (BPI)	63342*	63140		15875	
Rotational speed (RPM)	3755/2400**	2942*-4325	3000	2400	2700
PERFORMANCE					
Buffer/cache size (Kbytes)	1000	4000		64	1000
Servo type	Continuous	Continuous	Sampled	Sampled	Sampled
Average positioning time (msec)	19/21**	20	42	53	43
Average rotational delay (msec)	8/12.5**		10	12.5	11.1
Average access time (msec)	27/33.5**		52	65.5	54.1
Spin-up/Spin-down times (sec)	3/2	3.5/1.9*			
Data transfer rate (MBytes/sec) Internal External	 4.3/3.5** 10.0 synch.	 6 RD/3.5 WR 10.0 synch.	 5.3 1.4-2.6	 .635 2.4	 1.2-2.2 5.3
SIZE (mm: H x W x D)	41 x 146 x 210.3	41 x 146 x 210.3	41.3 x 147 x 203	41.3 x 146 x 203.2	42 x 147 x 210
FIRST CUSTOMER SHIPMENT	4Q96	3Q98	1Q95	2Q93	2Q96
COMMENTS	*1,7 RLL Code. **At highest capacity.	Purchased mechanism. *At 2.6 GB capacity.	DE-SH2200 is external mount.	DE-SH7101 is external mount.	DE-SH9101 is external mount.

MANUFACTURER	PLASMON LMS	PLASMON LMS	SONY	SONY	SONY
OPTICAL DRIVE	Infinity 6000 LD 6100	Infinity 8000 LD 8000	RMO-S591 RMO-S594	RMO-S594/DWP	SMO-F541 SMO-F544
DISK/TREND GROUP	24	24	23	23	23
MARKET	OEM, DIST	OEM, DIST	OEM, DIST	DIST	OEM, DIST
MEDIA: Disk diameter	300 mm	300 mm	130 mm	130 mm	130 mm
Recording technology	Ablative	Phase Change	Magneto-Optic	Magneto-Optic	Magneto-Optic
DRIVE: Operating mode	Write Once	Write Once	Rewritable	Rewritable	Rewritable
Direct overwrite	No	No		Yes	
Interface	SCSI-2	SCSI-2	SCSI-2	SCSI-2	SCSI-2
Speed control	CAV	CAV	ZCAV	ZCAV	ZCAV
CAPACITY/RECORDING DENSITY					
On-line capacity (Gigabytes) Capacity per disk (Gigabytes)	F: 12.000	F: 30 F: 30	F: .650/1.30 F: 1.3/2.6	F:.325*/.65/1.3 F:.650/1.3/2.6	F: .650/1.30 F: 1.3/2.6
Data surfaces per spindle	2	2	1	1	1
Tracks per surface	63000		26010*	26010	26010*
Track density (TPI)	NS		22100	22100	22100
Maximum linear density (BPI)	NS		51000	51000	51000
Rotational speed (RPM)	858	960	3600	3600	3600
PERFORMANCE					
Buffer/cache size (Kbytes)	2000	12000	1000, 4000	4000	1000, 4000
Servo type	Sampled		Continuous	Continuous	Continuous
Average positioning time (msec)	65	65	25	25	25
Average rotational delay (msec)	35	31.3	8.3	8.3	8.3
Average access time (msec)	100	96	33.3	33.3	33.3
Spin-up/Spin-down times (sec)	3.0/1.5	3.0/1.5	2.5/2.2	2.5/2.2	2.5/2.2
Data transfer rate (MBytes/sec) Internal External	2.7 RD/1.3 WR 10.0 synch.	6.2 RD/2.5 WR 20.0 synch.	2.0-4.0 5.0 synch.	2.0-4.0 10.0 synch.	2.0-4.0 5.0 synch.
SIZE (mm: H x W x D)	178 x 475 x 683		70 x 211 x 293	70 x 211 x 293	41.4 x 146 x 203
FIRST CUSTOMER SHIPMENT	2Q95		1Q96	2Q97	1Q96
COMMENTS	Dual head drive	Preliminary specification.	*75735 logical tracks.	*Read only.	*75735 logical tracks. F544 has 4 MB buffer.

MANUFACTURER	SONY	SONY	SONY	TERASTOR	TERASTOR
OPTICAL DRIVE	SMO-F544DW	SMO-F551	SMO-S551 RMO-S551	10GB	20GB
DISK/TREND GROUP	23	23	23	24	24
MARKET	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST
MEDIA: Disk diameter	130 mm	130 mm	130 mm	130 mm	130 mm
Recording technology	Magneto-Optic	Magneto-Optic	Magneto-Optic	Magneto-Optic	Magneto-Optic
DRIVE: Operating mode	Rewritable	Multifunct-(MO)	Multifunct-(MO)	Rewritable	Rewritable
Direct overwrite	Yes			Yes	Yes
Interface	SCSI-2	SCSI-2	SCSI-2	Ultra SCSI	Ultra SCSI
Speed control	CAV	ZCAV	ZCAV	CAV	CAV
CAPACITY/RECORDING DENSITY					
On-line capacity (Gigabytes) Capacity per disk (Gigabytes)	F: .650/1.30 F: 1.3/2.6	F: 1.3/2.6 F: 2.6/5.2	F: 1.3/2.6 F: 2.6/5.2	F: 10 F: 10	F: 20 F: 20
Data surfaces per spindle	1	1	1	1	1
Tracks per surface	26010*	38136	38136		
Track density (TPI)	22100	29780	29780		
Maximum linear density (BPI)	51000	63140	63140		
Rotational speed (RPM)	3600	3300/3600	3300/3600		
PERFORMANCE					
Buffer/cache size (Kbytes)	4000	4000	4000		
Servo type	Continuous	Continuous	Continuous		
Average positioning time (msec)	25	25	25	18	18
Average rotational delay (msec)	8.3	8.3/9.1	8.3/9.1		
Average access time (msec)	33.3	33.3/34.1	33.3/34.1		
Spin-up/Spin-down times (sec)	2.5/2.2	5.5/3.5	5.5/3.5		
Data transfer rate (MBytes/sec) Internal External	2.0-4.0 10.0 synch.	1.97-5.07 10.0 synch.	1.97-5.07 10.0 synch.	40 max. 6	40 max. 11
SIZE (mm: H x W x D)	41.4 x 146 x 203	41.3 x 146 x 203	70 x 211 x 293		
FIRST CUSTOMER SHIPMENT	2Q97	2Q98	2Q98	4Q99	4Q99
COMMENTS	*75735 logical tracks. F544 has 4 MB buffer.		External mount.	Preliminary specification. Near Field Recording.	Preliminary specification. Near Field Recording.

RIGID DISK CARTRIDGE DRIVE SPECIFICATIONS

RIGID DISK CARTRIDGE DRIVE SPECIFICATIONS

Coverage

This section includes removable rigid disk cartridge drives intended for computer data storage which are now new production or announced, arranged alphabetically by manufacturer. The product specifications use the same format employed in the DISK/TREND Report on rigid disk drives.

Capacities

Formatted capacities are given for all drives with embedded controllers, such as SCSI or IDE. Specific formatted capacities are indicated by "F". Capacities per track are listed for drives without zoned recording.

Average access time

All DISK/TREND specifications use the term "average access time" to describe the combination of average head positioning time and average disk rotational delay. Some in the industry have fallen into the habit of using the term average access time to describe average positioning time, or "seek" time, but this usage fails to adequately describe the time required for a disk drive to start to respond to a system request. The DISK/TREND specifications show separately the average positioning time, average rotational delay, and average access time, in order to avoid confusion.

Interfaces

Specific interfaces available are indicated for most drives, using references to manufacturers' own unique interfaces or to industry standards, either de facto or formalized. However, this is a rapidly changing area for noncaptive drives, so please be alert to the need to check for manufacturers' latest information if you need precise data. In particular, there are many noninterchangeable forms of SCSI interfaces.

Transfer rate

The transfer rate shown in the specifications is the rate at which data is transferred between the drive and the computer to which it is attached, in the case of drives with embedded controllers. If the manufacturer has specified more than one communication mode, such as synchronous and asynchronous, both data rates are indicated.

Accuracy

All information in this section has been cross-checked for accuracy. However, it is anticipated that some errors may be included, since many manufacturers' published specifications do not cover all of the items listed, and numerous verbal inquiries have been required.

1999 DISK/TREND Optical and Removable Disk Drive product groups

Group number	Drives included
CD format optical disk drives	
20:	CD format read-only optical disk drives.
21:	DVD format read-only optical disk drives.
22:	CD/DVD format writable optical disk drives.
Read/write optical disk drives	
23	Read/Write optical disk drives, less than 4 gigabytes.
24	Read/Write optical disk drives, more than 4 gigabytes.
Removable rigid disk drives	
1	Rigid disk cartridge drives.
2	Card format rigid disk drives.
Flexible disk drives	
13	High capacity flexible disk drives.
14	Low capacity flexible disk drives.

MANUFACTURER	CASTLEWOOD SYSTEMS	CASTLEWOOD SYSTEMS	CASTLEWOOD SYSTEMS	CASTLEWOOD SYSTEMS	CASTLEWOOD SYSTEMS
DRIVE	ORB2I100 IDE Internal	ORB2PE00 Parallel Port	ORB2SE00 SCSI External	ORB2SI00 SCSI Internal	ORB2UE00 USB External
DISK/TREND GROUP	1	1	1	1	1
MARKET	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST
MEDIA: Disk diameter	95 mm	95 mm	95 mm	95 mm	95 mm
Recording medium	Thin Film	Thin Film	Thin Film	Thin Film	Thin Film
DRIVE: Heads	MR Thin Film	MR Thin Film	MR Thin Film	MR Thin Film	MR Thin Film
Interface	IDE	Parallel Port	Ultra SCSI	Ultra SCSI	USB
CAPACITY/RECORDING DENSITY					
Total capacity (Mbytes) FIXED	--	--	--	--	--
REMOVABLE	F: 2,200	F: 2,200	F: 2,200	F: 2,200	F: 2,200
Capacity per track (Bytes)	Varies by zone	Varies by zone	Varies by zone	Varies by zone	Varies by zone
Data surfaces per spindle	2	2	2	2	2
Tracks per surface	8589	8589	8589	8589	8589
Track density (TPI)	9300	9300	9300	9300	9300
Maximum linear density (BPI) (FCI)	181000 204000	181000 204000	181000 204000	181000 204000	181000 204000
Areal density (Mb/square inch)	1.683	1.683	1.683	1.683	1.683
Recording code	8,9 PRML	8,9 PRML	8,9 PRML	8,9 PRML	8,9 PRML
Rotational speed (RPM)	5400	5400	5400	5400	5400
PERFORMANCE					
Actuator type	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil
Servo type	Embedded	Embedded	Embedded	Embedded	Embedded
Average positioning time (msec)	10 RD/12 WR	10 RD/12 WR	10 RD/12 WR	10 RD/12 WR	10 RD/12 WR
Average rotational delay (msec)	5.6	5.6	5.6	5.6	5.6
Average access time (msec)	15.6 RD/17.6 WR	15.6 RD/17.6 WR	15.6 RD/17.6 WR	15.6 RD/17.6 WR	15.6 RD/17.6 WR
Data transfer rate (MBytes/sec) Internal, min/max External	6.9/12.2 2.2	6.9/12.2 16.6 PIO Mode 4 16.6 DMA Mode 2	6.9/12.2 20.0 synch.	6.9/12.2 20.0 synch.	6.9/12.2 20.0
SIZE: (mm) H x W x D	25.4 x 101.1 x 152.4	38.1 x 133.4 x 165.1	38.1 x 133.4 x 165.1	25.4 x 101.6 x 152.4	38.1 x 133.4 x 165.1
FIRST CUSTOMER SHIPMENT	11/98	4/99	5/99	5/99	2Q99
COMMENTS	Internal model.	External model.	External model.	Internal model.	External model.

MANUFACTURER	IOMEGA	IOMEGA	IOMEGA	IOMEGA	
DRIVE	Jaz 1 Internal	Jaz 1 Portable	Jaz 2 Internal	Jaz 2 Portable	
DISK/TREND GROUP	1	1	1	1	
MARKET	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST	
MEDIA: Disk diameter	95 mm	95 mm	95 mm	95 mm	
Recording medium	Thin Film	Thin Film	Thin Film	Thin Film	
DRIVE: Heads	Thin Film	Thin Film	Thin Film	Thin Film	
Interface	SCSI-2	Ultra SCSI	Ultra SCSI	Ultra SCSI	
CAPACITY/RECORDING DENSITY					
Total capacity (Mbytes) FIXED	--	--	--	--	
REMOVABLE	F: 540/1,070	F: 540/1,070	F: 1,070/2,002	F: 1,070/2,002	
Capacity per track (Bytes)	Varies by zone	Varies by zone	Varies by zone	Varies by zone	
Data surfaces per spindle	4	4	4	4	
Tracks per surface	4204	4204	6145	6145	
Track density (TPI)	4301	4301	6100	6100	
Maximum linear density (BPI) (FCI)	89178 66884	89178 66884	121330 91000	121330 91000	
Areal density (Mb/square inch)	.384	.384	.740	.740	
Recording code	1,7 RLL	1,7 RLL	1,7 RLL	1,7 RLL	
Rotational speed (RPM)	5400	5400	5400	5400	
PERFORMANCE					
Actuator type	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	
Servo type	Embedded	Embedded	Embedded	Embedded	
Average positioning time (msec)	10 RD/12 WR	10 RD/12 WR	10 RD/12 WR	10 RD/12 WR	
Average rotational delay (msec)	5.6	5.6	5.6	5.6	
Average access time (msec)	15.6 RD/17.6 WR	15.6 RD/17.6 WR	15.6 RD/17.6 WR	15.6 RD/17.6 WR	
Data transfer rate (MBytes/sec) Internal, min/max External	3.5/6.7 10.0 synch. 5.0 asynch.	3.5/6.7 10.0 synch. 5.0 asynch.	4.9/8.7 20.0 synch. 5.0 asynch.	4.9/8.7 20.0 synch. 5.0 asynch.	
SIZE: (mm) H x W x D	25.4 x 101.6 x 149.9	38 x 135 x 203	25.4 x 101.6 x 149.9	38 x 135 x 203	
FIRST CUSTOMER SHIPMENT	4Q95	4Q95	3/98	3/98	
COMMENTS			Backward compatible with Jaz 1 GB disks.	Backward compatible with Jaz 1 GB disks.	

CARD FORMAT RIGID DISK DRIVE SPECIFICATIONS

CARD FORMAT RIGID DISK DRIVE SPECIFICATIONS

Coverage

This section includes removable rigid disk drives packaged in PCMCIA and CompactFlash form factors, known as "PC Card" or "CompactFlash Card" drives, intended for data storage which are now in new production or announced, arranged alphabetically by manufacturer. Product specifications use the same format employed in the DISK/TREND Report on rigid disk drives.

Capacities

Formatted native capacity has been used to determine the appropriate DISK/TREND product group for each drive in this product group, with specific formatted capacities indicated by "F".

Interfaces

Specific interfaces available are indicated for most drives, using references to manufacturers' own unique interfaces or to industry standards, either de facto or formalized. However, this is a rapidly changing area, so please be alert to the need to check for manufacturers' latest information if you need precise data. Most PC Card drives currently available adhere to the PCMCIA-ATA interface specifications.

Average access time

All DISK/TREND specifications use the term "average access time" to describe the combination of average head positioning time and average disk rotational delay. Some in the industry have fallen into the habit of using the term average access time to describe average positioning time, or "seek" time, but this usage fails to adequately describe the time required for a disk drive to start to respond to a system request. The DISK/TREND specifications show separately the average positioning time, average rotational delay, and average access time, in order to avoid confusion.

Transfer rate

The transfer rate shown in the specifications is the rate at which data is transferred between the drive and the computer to which it is attached, in the case of drives with embedded controllers. If the manufacturer has specified more than one communication mode, such as synchronous and asynchronous, both data rates are indicated.

Accuracy

All information in this section has been cross-checked for accuracy. However, it is anticipated that some errors may be included, since many manufacturers' published specifications do not cover all of the items listed, and numerous verbal inquiries have been required.

1999 DISK/TREND Optical and Removable Disk Drive product groups

Group number	Drives included
CD format optical disk drives	
20:	CD format read-only optical disk drives.
21:	DVD format read-only optical disk drives.
22:	CD/DVD format writable optical disk drives.
Read/write optical disk drives	
23	Read/Write optical disk drives, less than 4 gigabytes.
24	Read/Write optical disk drives, more than 4 gigabytes.
Removable rigid disk drives	
1	Rigid disk cartridge drives.
2	Card format rigid disk drives.
Flexible disk drives	
13	High capacity flexible disk drives.
14	Low capacity flexible disk drives.

MANUFACTURER	CALLUNA TECHNOLOGY	CALLUNA TECHNOLOGY	CALLUNA TECHNOLOGY	HALO DATA DEVICES	IBM
DRIVE	CT-1040RM callunacard	CT-260T2 callunacard	CT-521RM callunacard	Halo Ultra (Preliminary)	DMDM-10170 Microdrive 170
DISK/TREND GROUP	2	2	2	2	2
PLATFORM	Mobile	Mobile	Mobile	Mobile	Mobile
MARKET	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST
MEDIA: Disk diameter	48 mm	48 mm	48 mm	Approx. 1"	Approx. 1"
Recording medium	Thin Film	Thin Film	Thin Film	Thin Film	Thin Film
Substrate	Glass	Glass	Glass	Glass	Glass
DRIVE: Heads	MR Thin Film	MR Thin Film	MR Thin Film	GMR Thin Film	GMR Thin Film
Interface	PCMCIA-ATA	PCMCIA-ATA	PCMCIA-ATA	Compact Flash	Compact Flash
CAPACITY/RECORDING DENSITY Total capacity (Mbytes) FIXED	--	--	--	--	--
REMOVABLE	F: 1,040	F: 260	F: 520	F: 265	F: 170
Data surfaces per spindle	4	1	2	1	1
Tracks per surface	4030	4030	4030		
Track density (TPI)	9000	9000	9000		19000
Maximum linear density (BPI) (FCI)	169520	169520	169520		265100
Areal density (Gb/square inch)	1.526	1.526	1.526		5.037
Recording code	1,7 PRML	1,7 PRML	1,7 PRML		
Rotational speed (RPM)	3750	3750	3750	5400	4500
PERFORMANCE Actuator type	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil
Servo type	Embedded	Embedded	Embedded	Embedded	Embedded
Average positioning time (msec)	12	12	12	14	15
Average rotational delay (msec)	8	8	8	5.6	6.7
Average access time (msec)	20	20	20	19.6	21.7
Data transfer rate (MBytes/sec) Internal, min/max External	3.7/5.9 20.0	3.7/5.9 20.0	3.7/5.9 20.0	4.7/9.4	2.8/5.7 5.2
SIZE: (mm) H x W x D	10.5 x 54 x 85.6	5 x 54 x 85.6	10.5 x 54 x 85.6	3.3 x 36.4 x 42.8	5.0 x 42.8 x 36.4
FIRST CUSTOMER SHIPMENT	10/98	2Q99	10/98		6/99
COMMENTS	PCMCIA Type III	PCMCIA Type II.	PCMCIA Type III	Compact Flash Type I.	Compact Flash Type II.

MANUFACTURER	IBM	PCS, INC.	PCS, INC.		
DRIVE	DMDM-10340 Microdrive 340	8170E Viper 170E (Integral Peripherals)	8340PA Viper 340 (Integral Peripherals)		
DISK/TREND GROUP	2	2	2		
PLATFORM	Mobile	Mobile	Mobile		
MARKET	OEM, DIST	OEM	OEM		
MEDIA: Disk diameter	Approx. 1"	48 mm	48 mm		
Recording medium	Thin Film	Thin Film*	Thin Film*		
Substrate	Glass				
DRIVE: Heads	GMR Thin Film	Thin Film	Thin Film		
Interface	Compact Flash	PCMCIA-ATA	PCMCIA-ATA		
CAPACITY/RECORDING DENSITY Total capacity (Mbytes) FIXED	--	--	--		
REMOVABLE	F: 340	F: 170.8	F: 341.1		
Data surfaces per spindle	2	2	4		
Tracks per surface		2000	2000		
Track density (TPI)	19000	5100	5100		
Maximum linear density (BPI) (FCI)	265100	123600 92700	123600 92700		
Areal density (Gb/square inch)	5.037	.630	.630		
Recording code		1,7 PRML	1,7 PRML		
Rotational speed (RPM)	4500	4500	4500		
PERFORMANCE Actuator type	Rotary, Voice Coil	Rotary, Voice Coil	Rotary, Voice Coil		
Servo type	Embedded	Embedded	Embedded		
Average positioning time (msec)	15	12	12		
Average rotational delay (msec)	6.7	6.7	6.7		
Average access time (msec)	21.7	18.7	18.7		
Data transfer rate (MBytes/sec) Internal, min/max External	2.8/5.7 5.2	--/5.7 16.0	--/5.7 16.0		
SIZE: (mm) H x W x D	5.0 x 42.8 x 36.4	10.5 x 54 x 85.6	10.5 x 54 x 85.6		
FIRST CUSTOMER SHIPMENT	6/99	7/94	7/94		
COMMENTS	Compact Flash Type II.	PCMCIA Type III Ramp loaded heads. *Untextured disks.	PCMCIA Type III Ramp loaded heads. *Untextured disks.		

HIGH CAPACITY FLEXIBLE DISK DRIVE SPECIFICATIONS

HIGH CAPACITY
FLEXIBLE DISK DRIVE SPECIFICATIONS

Coverage

This section includes high capacity flexible disk drives intended for computer data storage, with capacities exceeding five megabytes, which are now in production or announced, arranged alphabetically by manufacturer. Product specifications use the same format employed in the separate DISK/TREND Report on flexible disk drives published in previous years.

Specifications of flexible disk drive models sold by computer system manufacturers or other firms, but purchased on an OEM basis from others, may be included in a few cases for clarity. In the case of captive flexible disk drives manufactured by some system manufacturers, captive drives which are similar to individual OEM/Integrator models made by the same system manufacturer are usually not listed.

Capacities

Formatted native capacities have been used to be consistent with the disk drive industry's trend to identify all drives by formatted capacities. All capacities are per individual drive. Capacities per track are listed, except for drives with zoned recording.

Average access time

DISK/TREND Reports use the term "average access time" to describe the combination of average head positioning time and average disk rotational delay. Some in the industry have fallen into the habit of using the term average access time to describe average positioning time, or "seek" time, but this usage fails to adequately describe the time required for a disk drive to start to respond to a system request. In this product group, average positioning time is given in the comments section for several drives, due to the higher performance provided by the coil actuators utilized. In some cases, settling time is included in the total for average positioning time.

Accuracy

All information has been cross-checked for accuracy. However, it is anticipated that some errors may be included, since many manufacturers' published specifications do not cover all of the items listed, and numerous verbal inquiries were necessary.

1999 DISK/TREND Optical and Removable Disk Drive product groups

Group number	Drives included
CD format optical disk drives	
20:	CD format read-only optical disk drives.
21:	DVD format read-only optical disk drives.
22:	CD/DVD format writable optical disk drives.
Read/write optical disk drives	
23	Read/Write optical disk drives, less than 4 gigabytes.
24	Read/Write optical disk drives, more than 4 gigabytes.
Removable rigid disk drives	
1	Rigid disk cartridge drives.
2	Card format rigid disk drives.
Flexible disk drives	
13	High capacity flexible disk drives.
14	Low capacity flexible disk drives.

MANUFACTURER	ALPS ELECTRIC	CALEB TECHNOLOGY	IMATION	IMATION	IMATION
DRIVE	HiFD	UHD 144	SuperDisk LS-120 Parallel Port External Model	SuperDisk LS-120 USB Interface For Macintosh External Model	SuperDisk LS-120 IDE/ATAPI Inter Internal Model
DISK/TREND GROUP	13	13	13	13	13
MARKET	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST
MEDIA: Nominal disk diameter	3.5"	3.5"	3.5"	3.5"	3.5"
Recording medium	Metal Powder	Metal Powder	Metal Powder	Metal Powder	Metal Powder
CAPACITY/RECORDING DENSITY					
Total capacity (Mbytes)	F: 200/1.44	F: 144/1.44	F: 120/1.44	F: 120/1.44	F: 120/1.44
Capacity per track (Bytes)	Varies by zone	Varies by zone	Varies by zone	Varies by zone	Varies by zone
Data surfaces per spindle	2	2	2	2	2
Tracks per surface		2011/80	1736/80	1736/80	1736/80
Track density (TPI)	2822	2881/135	2490/135	2490/135	2490/135
Maximum linear density (BPI)	91000	56250/17434	44880 BPI 33660 FCI	44880 BPI 33660 FCI	44880 BPI 33660 FCI
Recording code	16,17 PRML	1,7 RLL/MFM	1,7 RLL/MFM	1,7 RLL/MFM	1,7 RLL/MFM
Rotational speed (RPM)	3600/300	1000/600	1440	1440	1440
PERFORMANCE					
Actuator type	Linear, Voice Coil	Linear, Voice Coil	Linear, Voice Coil	Linear, Voice Coil	Linear, Voice Coil
POSITIONING: Track to track(msec)		3/25	10/15	10/15	10/15
Settling time (msec)		--	--	--	--
Average rotational delay (msec)	8.3	30/50	20.8	20.8	20.8
Data transfer rate (KBytes/sec)	3600	760/104.2	750*	958*	1100*
SIZE (mm: H x W x D)	25.4 x 101.6 x 159.5	25.4 x 101.6 x 150.0	40 x 150 x 220	40 x 135 x 196	25.4 x 101.6 x 153
FIRST CUSTOMER SHIPMENT		3Q99	2Q97	8/98	
COMMENTS	Downward compatible with 1.44 MB.	28 msec average positioning time. Downward compatible with 720 KB/1.44 MB. Interfaces available: ATAPI, PC Card, Parallel port, USB.	*Parallel port. 60 msec average positioning time. Downward compatible 720 KB/1.2 MB/ 1.44 MB.	*USB Interface. 60 msec average positioning time. Downward compatible 720 KB/1.2 MB/ 1.44 MB.	*IDE/ATAPI interface. 60 msec average positioning time. Downward compatible 720 KB/1.2 MB/ 1.44 MB.

MANUFACTURER	IMATION	IMATION	IOMEGA	IOMEGA	IOMEGA
DRIVE	SuperDisk LS-120 PC Card Inter. External Model	SuperDisk LS-120 USB Interface For PC/Mac External Model	Clik! Internal Model	Clik! Mobile Drive	Clik! PC Card Drive
DISK/TREND GROUP	13	13	13	13	13
MARKET	OEM, DIST	OEM, DIST	OEM	DIST	DIST
MEDIA: Nominal disk diameter	3.5"	3.5"	47 mm	47 mm	47 mm
Recording medium	Metal Powder	Metal Powder	Metal Powder	Metal Powder	Metal Powder
CAPACITY/RECORDING DENSITY					
Total capacity (Mbytes)	F: 120/1.44	F: 120/1.44	F: 40	F: 40	F: 40
Capacity per track (Bytes)	Varies by zone	Varies by zone	Varies by zone	Varies by zone	Varies by zone
Data surfaces per spindle	2	2	2	2	2
Tracks per surface	1736/80	1736/80			
Track density (TPI)	2490/135	2490/135			
Maximum linear density (BPI)	44880 BPI 33660 FCI	44880 BPI 33660 FCI			
Recording code	1,7 RLL/MFM	1,7 RLL/MFM			
Rotational speed (RPM)	1440	1440	2941	2941	2941
PERFORMANCE					
Actuator type	Linear, Voice Coil	Linear, Voice Coil			Linear, Voice Coil
POSITIONING: Track to track(msec)	10/15	10/15			
Settling time (msec)	--	--	--	--	--
Average rotational delay (msec)	20.8	20.8	10.2	10.2	10.2
Data transfer rate (KBytes/sec)	440*	958*	620	620	700
SIZE (mm: H x W x D)	17.0 x 101.6 x 154.9	40 x 135 x 196	7.3 x 54.2 x 85.9	30.5 x 69.9 x 116.8	5.0 x 54.0 x 85.6
FIRST CUSTOMER SHIPMENT		8/99	1Q99	1Q99	3Q99
COMMENTS	*PC Card interface. 60 msec average positioning time. Downward compatible 720 KB/1.2 MB/ 1.44 MB.	*USB interface. 60 msec average positioning time. Downward compatible 720 KB/1.2 MB/ 1.44 MB.	25 msec average positioning time.	25 msec average positioning time.	25 msec average positioning time. Uses PC Card Type II slot.

MANUFACTURER	IOMEGA	IOMEGA	IOMEGA	IOMEGA	IOMEGA
DRIVE	Notebook Zip ATAPI Interface	Zip 100 USB Interface External Model	Zip 100 ATAPI Interface Internal Model	Zip 100 Parallel Port External Model	Zip 100 SCSI Interface External Model
DISK/TREND GROUP	13	13	13	13	13
MARKET	OEM, DIST	OEM, DIST	OEM, DIST	DIST	DIST
MEDIA: Nominal disk diameter	3.5"	3.5"	3.5"	3.5"	3.5"
Recording medium	Metal Powder	Metal Powder	Metal Powder	Metal Powder	Metal Powder
CAPACITY/RECORDING DENSITY					
Total capacity (Mbytes)	F: 100	F: 100	F: 100	F: 100	F: 100
Capacity per track (Bytes)	Varies by zone	Varies by zone	Varies by zone	Varies by zone	Varies by zone
Data surfaces per spindle	2	2	2	2	2
Tracks per surface	1817	1817	1817	1817	1817
Track density (TPI)	2116	2116	2116	2116	2116
Maximum linear density (BPI)	46000 BPI 34500 FCI	46000 BPI 34500 FCI	46000 BPI 34500 FCI	46000 BPI 34500 FCI	46000 BPI 34500 FCI
Recording code	1,8 RLL	1,8 RLL	1,8 RLL	1,8 RLL	1,8 RLL
Rotational speed (RPM)	2941	2941	2941	2941	2941
PERFORMANCE					
Actuator type	Linear, Voice Coil	Linear, Voice Coil	Linear, Voice Coil	Linear, Voice Coil	Linear, Voice Coil
POSITIONING: Track to track(msec)	4	4	4	4	4
Settling time (msec)	--	--	--	--	--
Average rotational delay (msec)	10.2	10.2	10.2	10.2	10.2
Data transfer rate (KBytes/sec)	1400	1500	1400	1400	4000 synch.
SIZE (mm: H x W x D)	12.7 x 99.5 x 135	25.4 x 101.4 x 163.6	25.4 x 101.4 x 163.6	37.3 x 135.9 x 180.3	37.3 x 135.9 x 180.3
FIRST CUSTOMER SHIPMENT	1998	4Q98	1Q96	3/95	3/95
COMMENTS	29 msec average positioning time.	29 msec average positioning time.	29 msec average positioning time.	29 msec average positioning time.	29 msec average positioning time.

MANUFACTURER	IOMEGA	IOMEGA	IOMEGA	IOMEGA	IOMEGA
DRIVE	Zip 100 SCSI Interface Internal Model	Zip 250 SCSI Interface External Model	Zip 250 Parallel Port External Model	Zip 250 ATAPI Interface Internal Model	Zip Plus 100 SCSI/Para. Port Internal Model
DISK/TREND GROUP	13	13	13	13	13
MARKET	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST
MEDIA: Nominal disk diameter	3.5"	3.5"	3.5"	3.5"	3.5"
Recording medium	Metal Powder	Metal Powder	Metal Powder	Metal Powder	Metal Powder
CAPACITY/RECORDING DENSITY					
Total capacity (Mbytes)	F: 100	F: 250	F: 250	F: 250	F: 100
Capacity per track (Bytes)	Varies by zone	Varies by zone	Varies by zone	Varies by zone	Varies by zone
Data surfaces per spindle	2	2	2	2	2
Tracks per surface	1817				1817
Track density (TPI)	2116				2116
Maximum linear density (BPI)	46000 BPI 34500 FCI				46000 BPI 34500 FCI
Recording code	1,8 RLL				1,8 RLL
Rotational speed (RPM)	2941	2941	2941	2941	2941
PERFORMANCE					
Actuator type	Linear, Voice Coil	Linear, Voice Coil	Linear, Voice Coil	Linear, Voice Coil	Linear, Voice Coil
POSITIONING: Track to track(msec)	4				4
Settling time (msec)	--				--
Average rotational delay (msec)	10.2	10.2	10.2	10.2	10.2
Data transfer rate (KBytes/sec)	4000 synch.	2400 synch.	800	2400	1400 synch.
SIZE (mm: H x W x D)	25.4 x 101.4 x 163.6	44 x 139 x 193	44 x 139 x 193	25.4 x 101.4 x 163.6	25.4 x 101.4 x 163.6
FIRST CUSTOMER SHIPMENT	2Q96	4Q98	4Q98	2Q99	1998
COMMENTS	29 msec average positioning time.	Downward compatible with 100 MB.	29 msec average positioning time. Downward compatible with 100 MB.	29 msec average positioning time. Downward compatible with 100 MB.	29 msec average positioning time.

MANUFACTURER	MATSUSHITA COMMUNICATION INDUSTRIAL	MATSUSHITA-KOTOBUKI ELECTRONICS	MATSUSHITA-KOTOBUKI ELECTRONICS	MATSUSHITA-KOTOBUKI ELECTRONICS	MATSUSHITA-KOTOBUKI ELECTRONICS
DRIVE	Zip 100 ATAPI Interface Internal Model	LK-RM120ZD	LK-RM864DZ	LKM-F734	LKM-F834
DISK/TREND GROUP	13	13	13	13	13
MARKET	DIST, OEM	OEM, DIST	DIST	OEM, DIST	OEM, DIST
MEDIA: Nominal disk diameter	3.5"	3.5"	3.5"	3.5"	3.5"
Recording medium	Metal Powder	Metal Powder	Metal Powder	Metal Powder	Metal Powder
CAPACITY/RECORDING DENSITY					
Total capacity (Mbytes)	F: 100	F: 120/1.44	F: 120/1.44	F: 120/1.44	F: 120/1.44
Capacity per track (Bytes)	Varies by zone	Varies by zone	Varies by zone	Varies by zone	Varies by zone
Data surfaces per spindle	2	2	2	2	2
Tracks per surface	1817	1736/80	1736/80	1736/80	1736/80
Track density (TPI)	2116	2490/135	2490/135	2490/135	2490/135
Maximum linear density (BPI)	46000 BPI 34500 FCI	44880 BPI 33660 FCI	44880 BPI 33660 FCI	44880 BPI 33660 FCI	44880 BPI 33660 FCI
Recording code	1,8 RLL	1,7 RLL/MFM	1,7 RLL/MFM	1,7 RLL/MFM	1,7 RLL/MFM
Rotational speed (RPM)	2941	720	720	720	720
PERFORMANCE					
Actuator type	Linear, Voice Coil	Linear, Voice Coil	Linear, Voice Coil	Linear, Voice Coil	Linear, Voice Coil
POSITIONING: Track to track(msec)	4	10/15	10/15	10/15	10/15
Settling time (msec)	--	--	--	--	--
Average rotational delay (msec)	10.2	41.7	41.7	41.7	41.7
Data transfer rate (KBytes/sec)	--*	4000	4000	680*	680*
SIZE (mm: H x W x D)	25.5 x 101.5 x 165	35 x 135 x 200	20.0 x 110 x 170	25.4 x 101.6 x 150	12.7 x 96 x 126
FIRST CUSTOMER SHIPMENT		2Q97	1Q98	3Q97	3Q97
COMMENTS	*ATAPI. 29 msec average positioning time. 25 and 100 MB disk cartridges available.	70 msec average positioning time. Downward compatible 720 KB/1.2 MB/ 1.44 MB. PCMCIA interface. Sold in Japan.	70 msec average positioning time. Downward compatible 720 KB/1.2 MB/ 1.44 MB. PCMCIA interface. Sold in Japan.	70 msec average positioning time. Downward compatible 720 KB/1.2 MB/ 1.44 MB. *ATAPI interface.	70 msec average positioning time. Downward compatible 720 KB/1.2 MB/ 1.44 MB. *ATAPI interface.

MANUFACTURER	MATSUSHITA-KOTOBUKI ELECTRONICS	MATSUSHITA-KOTOBUKI ELECTRONICS	MATSUSHITA-KOTOBUKI ELECTRONICS	MATSUSHITA-KOTOBUKI ELECTRONICS	MITSUBISHI ELECTRIC CORPORATION
DRIVE	LKM-F934	LKM-FB34-1	LKM-RM934UZ	LKM-RMB33	MF 357G SuperDisk LS-120
DISK/TREND GROUP	13	13	13	13	13
MARKET	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST
MEDIA: Nominal disk diameter	3.5"	3.5"	3.5"	3.5"	3.5"
Recording medium	Metal Powder	Metal Powder	Metal Powder	Metal Powder	Metal Powder
CAPACITY/RECORDING DENSITY					
Total capacity (Mbytes)	F: 120/1.44	F: 120/1.44	F: 120/1.44	F: 120/1.44	F: 120/1.44
Capacity per track (Bytes)	Varies by zone	Varies by zone	Varies by zone	Varies by zone	Varies by zone
Data surfaces per spindle	2	2	2	2	2
Tracks per surface	1736/80	1736/80	1736/80	1736/80	1736/80
Track density (TPI)	2490/135	2490/135	2490/135	2490/135	2490/135
Maximum linear density (BPI)	44880 BPI 33660 FCI	44880 BPI 33660 FCI	44880 BPI 33660 FCI	44880 BPI 33660 FCI	44880 BPI 33660 FCI
Recording code	1,7 RLL/MFM	1,7 RLL/MFM	1,7 RLL/MFM	1,7 RLL/MFM	1,7 RLL/MFM
Rotational speed (RPM)	1440	720	1440	720	720
PERFORMANCE					
Actuator type	Linear, Voice Coil	Linear, Voice Coil	Linear, Voice Coil	Linear, Voice Coil	Linear, Voice Coil
POSITIONING: Track to track(msec)	10/15	10/15	10/15	10/15	10/15
Settling time (msec)		--	--	--	--
Average rotational delay (msec)	20.8	41.7	41.7	41.7	41.7
Data transfer rate (KBytes/sec)	1360*	680*	958	1360	8300 (max.)
SIZE (mm: H x W x D)	25.4 x 101.6 x 150	12.7 x 96 x 126	39.3 x 136 x 196		25.4 x 101.6 x 150
FIRST CUSTOMER SHIPMENT	3Q98	3Q98	1999	1999	8/96
COMMENTS	65 msec average positioning time. Downward compatible 720 KB/1.2 MB/ 1.44 MB. *ATAPI interface.	70 msec average positioning time. Downward compatible 720 KB/1.2 MB/ 1.44 MB. *ATAPI interface.	65 msec average positioning time. Downward compatible 720 KB/1.2 MB/ 1.44 MB. USB interface.	65 msec average positioning time. Downward compatible 720 KB/1.2 MB/ 1.44 MB. USB interface.	70 msec average positioning time. Downward compatible 720 KB/1.2 MB/ 1.44 MB. ATAPI interface

MANUFACTURER	MITSUBISHI ELECTRIC CORPORATION	NEC	O.R. TECHNOLOGY	O.R. TECHNOLOGY	O.R. TECHNOLOGY
DRIVE	MF 357H SuperDisk LS-120 Slim	FZ 110A ZIP 100	EFD-2120A	EFD-3120A	EFD-3120PK Parallel Port External Model
DISK/TREND GROUP	13	13	13	13	13
MARKET	OEM, DIST	CAPT,DIST, OEM	OEM, DIST	OEM, DIST	OEM, DIST
MEDIA: Nominal disk diameter	3.5"	3.5"	3.5"	3.5"	3.5"
Recording medium	Metal Powder	Metal Powder	Metal Powder	Metal Powder	Metal Powder
CAPACITY/RECORDING DENSITY					
Total capacity (Mbytes)	F: 120/1.44	F: 100	F: 120/1.44	F: 120/1.44	F: 120/1.44
Capacity per track (Bytes)	Varies by zone	Varies by zone	Varies by zone	Varies by zone	Varies by zone
Data surfaces per spindle	2	2	2	2	2
Tracks per surface	1736/80	1817	1736/80	1736/80	1736/80
Track density (TPI)	2490/135	2116	2490/135	2490/135	2490/135
Maximum linear density (BPI)	44880 BPI 33660 FCI	46000 34500	44880 BPI 33660 FCI	44880 BPI 33660 FCI	44880 BPI 33660 FCI
Recording code	1,7 RLL/MFM	1-8 RLL	1,7 RLL/MFM	1,7 RLL/MFM	1,7 RLL/MFM
Rotational speed (RPM)	720	2941	1440	1440	1440
PERFORMANCE					
Actuator type	Linear, Voice Coil	Linear, Voice Coil	Linear, Voice Coil	Linear, Voice Coil	Linear, Voice Coil
POSITIONING: Track to track(msec)	10/15	4	6/15	6/15	6/15
Settling time (msec)	--	--	--	--	--
Average rotational delay (msec)	41.7	10.2	20.8	20.8	20.8
Data transfer rate (KBytes/sec)	8300 (max.)	1400	4000	4000	4000
SIZE (mm: H x W x D)	12.7 x 96 x 126	25.4 x 101.4 x 163.6	12.7 x 96 x 124	25.4 x 101.6 x 150	35 x 131 x 203
FIRST CUSTOMER SHIPMENT	7/97	11/97	2Q97	3Q96	1999
COMMENTS	70 msec average positioning time. Downward compatible 720 KB/1.2 MB/ 1.44 MB. ATAPI interface	ATAPI interface 29 msec average positioning time.	65 msec average positioning time. Downward compatible 720 KB/1.2 MB/ 1.44 MB.	65 msec average positioning time. Downward compatible 720 KB/1.2 MB/ 1.44 MB.	65 msec average positioning time. Downward compatible 720 KB/1.2 MB/ 1.44 MB.

MANUFACTURER	SAMSUNG ELECTRO-MECHANICS	SONY	SONY	SONY	TEAC
DRIVE	Pro-FD	SFD200-1 HiFD	SFD-200S-BP HiFD External	SFD20H-1 HiFD	FD-07 HiFD ATAPI Interface
DISK/TREND GROUP	13	13	13	13	13
MARKET	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST	OEM, DIST
MEDIA: Nominal disk diameter	3.5"	3.5"	3.5"	3.5"	3.5"
Recording medium		Metal Powder	Metal Powder	Metal Powder	Metal Powder
CAPACITY/RECORDING DENSITY					
Total capacity (Mbytes)	F: 123/.72/1.44	F: 200/1.44/.72	F: 200/1.44/.72	F: 200/1.44/.72	F: 200/1.44
Capacity per track (Bytes)	Varies by zone	Varies by zone	Varies by zone	Varies by zone	Varies by zone
Data surfaces per spindle	2	2	2	2	2
Tracks per surface	1796	1741	1741	1741	
Track density (TPI)	2600	2822	2822	2822	2822
Maximum linear density (BPI)	45764	86600	86600	86600 92100	91000
Recording code	1,7 RLL, MFM	16,17 EPR4	16,17 EPR4	16,17 EPR4	16,17 PRML
Rotational speed (RPM)	720	3600/300	3600/300	3600	3600/600
PERFORMANCE					
Actuator type	Lead Screw, Stepping Motor	Linear, Voice Coil	Linear, Voice Coil	Linear, Voice Coil	Linear, Voice Coil
POSITIONING: Track to track(msec)	3				
Settling time (msec)	--				
Average rotational delay (msec)	41.7	8.3/100	8.3/100	8.3/300	8.3
Data transfer rate (KBytes/sec)	625	3600 (max.)	600 (max.)	3600 (max.)	3600*
SIZE (mm: H x W x D)	25.4 x 101.4 x 149	25.4 x 101.6 x 163.5	42 x 143 x 214	12.7 x 101.6 x 126	12.7 x 101.6 x 126
FIRST CUSTOMER SHIPMENT	3Q99		9/99		
COMMENTS	35 msec average positioning time. Downward compatible 720 KB/1.44 MB. ATAPI interface	Downward compatible with 1.44 MB, 720 KB	Downward compatible with 1.44 MB. Parallel port interface. 49 msec average positioning time.	Downward compatible with 1.44 MB, 720 KB	Downward compatible with 1.44 MB. *ATAPI interface.

MANUFACTURER	TEAC	TEAC			
DRIVE	FD-200K HiFD External Parallel Port	HiFD Internal			
DISK/TREND GROUP	13	13			
MARKET	OEM, DIST	OEM, DIST			
MEDIA: Nominal disk diameter	3.5"	3.5"			
Recording medium	Metal Powder	Metal Powder			
CAPACITY/RECORDING DENSITY					
Total capacity (Mbytes)	F: 200/1.44	F: 200/1.44			
Capacity per track (Bytes)	Varies by zone	Varies by zone			
Data surfaces per spindle	2	2			
Tracks per surface					
Track density (TPI)	2822	2822			
Maximum linear density (BPI)	91000	91000			
Recording code	16,17 PRML	16,17 PRML			
Rotational speed (RPM)	3600/300	3600/300			
PERFORMANCE					
Actuator type	Linear, Voice Coil	Linear, Voice Coil			
POSITIONING: Track to track(msec)					
Settling time (msec)					
Average rotational delay (msec)	8.3	8.3			
Data transfer rate (KBytes/sec)	*	3600			
SIZE (mm: H x W x D)		25.4 x 101.6 x 145			
FIRST CUSTOMER SHIPMENT					
COMMENTS	Downward compatible with 1.44 MB. *Parallel port.	Downward compatible with 1.44 MB.			

LOW CAPACITY FLEXIBLE DISK DRIVE SPECIFICATIONS

LOW CAPACITY
FLEXIBLE DISK DRIVE SPECIFICATIONS

Coverage

This section includes low capacity flexible disk drives intended for data storage, with capacities less than five megabytes, which are now in production or announced, arranged alphabetically by manufacturer. Product specifications use the same format employed in the separate DISK/TREND Report on flexible disk drives published in previous years. Specifications of flexible disk drive models sold by computer system manufacturers, but purchased on an OEM basis from others, may be included in a few cases for clarity. In the case of captive flexible disk drives manufactured by system manufacturers, captive drives which are similar to individual OEM/Integrator models made by the same system manufacturer are usually not listed.

Capacities

Formatted native capacities have been used to be consistent with the disk drive industry's trend to identify all drives by formatted capacities. Capacities are listed as "F" for formatted. All capacities are per individual drive. Capacities per track are listed, except for drives with zoned recording.

Accuracy

All information has been cross-checked for accuracy. However, it is anticipated that some errors may be included, since many manufacturers' published specifications do not cover all of the items listed, and numerous verbal inquiries were necessary.

DISK/TREND product groups

In most cases the product groups used for individual drives are clear, but a few arbitrary decisions have been made. Please note that all drives with capacities under 5 megabytes have been placed in the low capacity group, regardless of disk diameter.

1999 DISK/TREND Optical and Removable Disk Drive product groups

Group number	Drives included
CD format optical disk drives	
20:	CD format read-only optical disk drives.
21:	DVD format read-only optical disk drives.
22:	CD/DVD format writable optical disk drives.
Read/write optical disk drives	
23	Read/Write optical disk drives, less than 4 gigabytes.
24	Read/Write optical disk drives, more than 4 gigabytes.
Removable rigid disk drives	
1	Rigid disk cartridge drives.
2	Card format rigid disk drives.
Flexible disk drives	
13	High capacity flexible disk drives.
14	Low capacity flexible disk drives.

MANUFACTURER	ALPS ELECTRIC	ALPS ELECTRIC	CITIZEN	CITIZEN	CITIZEN
DRIVE	DF 354H	DF 354N	BXW	OSDA	OSDE
DISK/TREND GROUP	14	14	14	14	14
MARKET	OEM, DIST	OEM, DIST	OEM	OEM	OEM
MEDIA: Nominal disk diameter	3.5"	3.5"	3.5"	3.5"	3.5"
Recording medium	High Density Oxide Coated	High Density Oxide Coated	High Density Oxide Coated	High Density Oxide Coated	High Density Oxide Coated
CAPACITY/RECORDING DENSITY					
Total capacity (Mbytes)	F: .7/1.4	F: .7/1.2/1.44	F: .7/1.2/1.4	F: .7/1.4	F: .7/1.2/1.4
Capacity per track (Bytes)	F: 4,608/9,216	F: 4,608/7,680/ 9,216	F: 4,608/9,216	F: 4,608/9,216	F: 4,608/9,216
Data surfaces per spindle	2	2	2	2	2
Tracks per surface	80	80/77/80	80/77/80	80	80/77/80
Track density (TPI)	135	135	135	135	135
Maximum linear density (BPI)	8717/17434	8717/14184/ 17434	8717/17434	8717/17434	8717/17434
Recording code	MFM	MFM	MFM	MFM	MFM
Rotational speed (RPM)	300	300/360/300	300/360	300	300
PERFORMANCE					
Actuator type	Lead Screw, Stepping Motor	Lead Screw, Stepping Motor	Lead Screw, Stepping Motor	Lead Screw, Stepping Motor	Lead Screw, Stepping Motor
POSITIONING: Track to track(msec)	3	3	3	3	3
Settling time (msec)	15	15	15	15	15
Average rotational delay (msec)	100/83.3	100/83.3	100/83.3	100	100
Data transfer rate (KBytes/sec)	31.25/62.5	31.25/62.5	31.25/62.5	31.25/62.5	31.25/62.5
SIZE (mm: H x W x D)	25.4 x 101.6 x 145	25.4 x 101.6 x 145	15 x 100 x 140	25.4 x 101.6 x 149.9	25.4 x 101.6 x 149.9
FIRST CUSTOMER SHIPMENT	12/95	12/95	1Q95	4Q87	4Q89
COMMENTS	Direct drive.	Direct drive.	External mount of W1 models.		

MANUFACTURER	CITIZEN	CITIZEN	MATSUSHITA COMMUNICATION INDUSTRIAL	MATSUSHITA COMMUNICATION INDUSTRIAL	MATSUSHITA COMMUNICATION INDUSTRIAL
DRIVE	W1DE	X1DE	JU-226A	JU-227A	JU-256A
DISK/TREND GROUP	14	14	14	14	14
MARKET	OEM	OEM	CAPT,OEM,DIST	CAPT,OEM,DIST	CAPT,OEM,DIST
MEDIA: Nominal disk diameter	3.5"	3.5"	3.5"	3.5"	3.5"
Recording medium	High Density Oxide Coated	High Density Oxide Coated	High Density Oxide Coated	High Density Oxide Coated	High Density Oxide Coated
CAPACITY/RECORDING DENSITY					
Total capacity (Mbytes)	F: .7/1.2/1.4	F: .7/1.2/1.4	F: .7/1.2/1.4	F: .7/1.4	F: .7/1.2/1.4
Capacity per track (Bytes)	F: 4,608/9,216	F: 4,608/9,216	F: 4,608/7,680/ 9,216	F: 4,608/9,216	F: 4,608/7,680/ 9,216
Data surfaces per spindle	2	2	2	2	2
Tracks per surface	80/77/80	80/77/80	80	80	80
Track density (TPI)	135	135	135	135	135
Maximum linear density (BPI)	8717/17434	8717/17434	17434	17434	17434
Recording code	MFM	MFM	MFM	MFM	MFM
Rotational speed (RPM)	300/360	300/360	300	300	300
PERFORMANCE					
Actuator type	Lead Screw, Stepping Motor	Lead Screw, Stepping Motor	Lead Screw, Stepping Motor	Lead Screw, Stepping Motor	Lead Screw, Stepping Motor
POSITIONING: Track to track(msec)	3	3	3	3	3
Settling time (msec)	15	15	15	15	15
Average rotational delay (msec)	100/83.3	100/83.3	100	100	100
Data transfer rate (KBytes/sec)	31.25/62.5	31.25/62.5	62.5	62.5	62.5
SIZE (mm: H x W x D)	11 x 96 x 116	12.7 x 96 x 126	12.7 x 101.6 x 106	12.7 x 101.6 x 106	25.4 x 101.6 x 149.9
FIRST CUSTOMER SHIPMENT	2Q93	3Q99	1994	1994	1994
COMMENTS					

MANUFACTURER	MATSUSHITA COMMUNICATION INDUSTRIAL	MITSUBISHI ELECTRIC CORPORATION	MITSUBISHI ELECTRIC CORPORATION	MITSUMI ELECTRIC	MITSUMI ELECTRIC
DRIVE	JU-257	MF 355F	MF 355H	D 353F3	D 353F3E
DISK/TREND GROUP	14	14	14	14	14
MARKET	CAPT,OEM,DIST	OEM	OEM	OEM	OEM
MEDIA: Nominal disk diameter	3.5"	3.5"	3.5"	3.5"	3.5"
Recording medium	High Density Oxide Coated	High Density Oxide Coated	High Density Oxide Coated	High Density Oxide Coated	High Density Oxide Coated
CAPACITY/RECORDING DENSITY					
Total capacity (Mbytes)	F: .7/1.4	F: .7/1.2/1.4	F: .7/1.2/1.4	F: .7/1.2/1.4	F: .7/1.2/1.4
Capacity per track (Bytes)	F: 4,608/9,216	F: 4,608/7,680 9,216	F: 4,608/7,680 9,216	F: 4,608/7,680 9,216	F: 4,608/7,860 9,216
Data surfaces per spindle	2	2	2	2	2
Tracks per surface	80	80	80	80/77	80/77
Track density (TPI)	135	135	135	135	135
Maximum linear density (BPI)	8717/17434	8717/14528/ 17434	8717/14528/ 17434	8717/14184/ 17424	8717/14184/ 17434
Recording code	MFM	MFM	MFM	MFM	MFM
Rotational speed (RPM)	300	300/360	300/360	300/360	300/360
PERFORMANCE					
Actuator type	Lead Screw, Stepping Motor	Lead Screw, Stepping Motor	Lead Screw, Stepping Motor	Lead Screw, Stepping Motor	Lead Screw, Stepping Motor
POSITIONING: Track to track(msec)	3	3	3	3	3
Settling time (msec)	15	15	15	15	15
Average rotational delay (msec)	100	100/83.3	100/83.3	100/83.3	100/83.3
Data transfer rate (KBytes/sec)	31.25/62.5	31.25/62.5	31.25/62.5	31.25/62.5	31.25/62.5
SIZE (mm: H x W x D)	25.4 x 101.6 x 149.9	25.4 x 101.6 x 146	12.7 x 96 x 126	12.7 x 96 x 130	17.5 x 106 x 143
FIRST CUSTOMER SHIPMENT	1987	1Q92	1Q94	3Q97	1Q95
COMMENTS			15 mm high version available with auto eject.		External model.

MANUFACTURER	MITSUMI ELECTRIC	MITSUMI ELECTRIC	MITSUMI ELECTRIC	NEC	NEC
DRIVE	D 353G	D 353M3	D 359M3	FD 1231H	FD 1231T
DISK/TREND GROUP	14	14	14	14	14
MARKET	OEM	OEM	OEM	CAPT,DIST, OEM	Captive, OEM
MEDIA: Nominal disk diameter	3.5"	3.5"	3.5"	3.5"	3.5"
Recording medium	High Density Oxide Coated	High Density Oxide Coated	High Density Oxide Coated	High Density Oxide Coated	High Density Oxide Coated
CAPACITY/RECORDING DENSITY					
Total capacity (Mbytes)	F: .7/1.2/1.4	F: .7/1.2/1.4	F: .7/1.4	F: .7/1.4	F: .7/1.2/1.4
Capacity per track (Bytes)	F: 4,608/7,680 9,216	F: 4,608/7,680 9,216	F: 4,608/9,216	F: 4,608/9,216	F: 4,608/7,680 9,216
Data surfaces per spindle	2	2	2	2	2
Tracks per surface	80/77	80/77	80	80	80
Track density (TPI)	135	135	135	135	135
Maximum linear density (BPI)	8717/14184/ 17434	8717/14184/ 17434	8717/17434	8717/17434	8717/14528/ 17434
Recording code	MFM	MFM	MFM	MFM	MFM
Rotational speed (RPM)	300/360	300/360	300	300	300/360
PERFORMANCE					
Actuator type	Lead Screw, Stepping Motor	Lead Screw, Stepping Motor	Lead Screw, Stepping Motor	Lead Screw, Stepping Motor	Lead Screw, Stepping Motor
POSITIONING: Track to track(msec)	3	3	3	3	3
Settling time (msec)	15	15	15	15	15
Average rotational delay (msec)	100/83.3	100/83.3	100	100	100
Data transfer rate (KBytes/sec)	31.25/62.5	31.25/62.5	31.25/62.5	31.25/62.5	31.25/62.5
SIZE (mm: H x W x D)	12.7 x 101.6 x 101.6	25.4 x 101.6 x 144	25.4 x 101.6 x 144	25.4 x 101.6 x 146	25.4 x 101.6 x 146
FIRST CUSTOMER SHIPMENT	2Q95	2Q97	2Q97	2Q95	2Q95
COMMENTS					

MANUFACTURER	NEC	NEC	SAMSUNG ELECTRO-MECHANICS	SAMSUNG ELECTRO-MECHANICS	SONY
DRIVE	FD 1238H	FD 1238T	SFD-321B	SFD-321S	MPF720
DISK/TREND GROUP	14	14	14	14	14
MARKET	Captive, OEM	Captive, OEM	Captive, OEM	Captive, OEM	CAPT,OEM, DIST
MEDIA: Nominal disk diameter	3.5"	3.5"	3.5"	3.5"	3.5"
Recording medium	High Density Oxide Coated	High Density Oxide Coated	High Density Oxide Coated	High Density Oxide Coated	High Density Oxide Coated
CAPACITY/RECORDING DENSITY					
Total capacity (Mbytes)	F: .7/1.4	F: .7/1.2/1.4	F: .7/1.2/1.4	F: .7/1.2/1.4	F: .7/1.2/1.4
Capacity per track (Bytes)	F: 4,608/9,216	F: 4,608/7,680 9,216	F: 4,608/7,680 9,216	F: 4,608/7,680 9,216	F: 4,608/7,680/ 9,216
Data surfaces per spindle	2	2	2	2	2
Tracks per surface	80	80	80	80	80
Track density (TPI)	135	135	135	135	135
Maximum linear density (BPI)	8717/17434	8717/14528/ 17434	8717/17434	8717/17434	8717/14528/ 17434
Recording code	MFM	MFM	MFM	MFM	MFM
Rotational speed (RPM)	300	300/360	300/360	300/360	300/360/300
PERFORMANCE					
Actuator type	Lead Screw, Stepping Motor	Lead Screw, Stepping Motor	Lead Screw, Stepping Motor	Lead Screw, Stepping Motor	Lead Screw, Stepping Motor
POSITIONING: Track to track(msec)	3	3	3	3	3
Settling time (msec)	15	15	15	15	15
Average rotational delay (msec)	100	100	100	100	100
Data transfer rate (KBytes/sec)	31.25/62.5	31.25/62.5	31.25/62.5	31.25/62.5	31.25/62.5/62.5
SIZE (mm: H x W x D)	12.7 x 96 x 126	12.7 x 96 x 126	25.4 x 101.6 x 145	12.7 x 96 x 126	12.7 x 96 x 130
FIRST CUSTOMER SHIPMENT	1Q95	1Q95			2Q95
COMMENTS					

MANUFACTURER	SONY	TEAC	TEAC	TEAC	TEAC
DRIVE	MPF920	FD-05HF	FD-05HG	FD-05HGS	FD-05PHG
DISK/TREND GROUP	14	14	14	14	14
MARKET	CAPT,OEM, DIST	OEM	OEM	OEM	OEM
MEDIA: Nominal disk diameter	3.5"	3.5"	3.5"	3.5"	3.5"
Recording medium	High Density Oxide Coated	High Density Oxide Coated	High Density Oxide Coated	High Density Oxide Coated	High Density Oxide Coated
CAPACITY/RECORDING DENSITY					
Total capacity (Mbytes)	F: .7/1.2/1.4	F: .7/1.4	F: .7/1.2/1.4	F: .7/1.2/1.4	F: .7/1.2/1.4
Capacity per track (Bytes)	F: 4,608/7,680/ 9,216	F: 4,608/9,216	F: 4,608/9,216	F: 4,608/9,216	F: 4,608/9,216
Data surfaces per spindle	2	2	2	2	2
Tracks per surface	80	80	80	80	80
Track density (TPI)	135	135	135	135	135
Maximum linear density (BPI)	8717/14528/ 17434	8717/17434	8717/17434	8717/17434	8717/17434
Recording code	MFM	MFM	MFM	MFM	MFM
Rotational speed (RPM)	300/360/300	300	300/360	300/360	300/360
PERFORMANCE					
Actuator type	Lead Screw, Stepping Motor	Lead Screw, Stepping Motor	Lead Screw, Stepping Motor	Lead Screw, Stepping Motor	Lead Screw, Stepping Motor
POSITIONING: Track to track(msec)	3	3	3	3	3
Settling time (msec)	15	15	15	15	15
Average rotational delay (msec)	100	100	100/83.3	100/83.3	100/83.3
Data transfer rate (KBytes/sec)	31.25/62.5/62.5	31.25/62.5	31.25/62.5	31.25/62.5	31.25/62.5
SIZE (mm: H x W x D)	25.4 x 101.6 x 146	12.7 x 101.6 x 129.5	12.7 x 101.6 x 129.5	25.4 x 101.6 x 144.5	15.5 x 106.2 x 146
FIRST CUSTOMER SHIPMENT	2Q96	10/91		2Q93	4/92
COMMENTS		Direct drive motor. 101.6 mm or 96 mm width available.	Direct drive motor. 101.6 mm or 96 mm width available.	SCSI interface.	External drive unit.

MANUFACTURER	TEAC	TEAC	TEAC	TEAC	TEAC
DRIVE	FD-05PU	FD-235GF	FD-235GS	FD-235HF	FD-235HG
DISK/TREND GROUP	14	14	14	14	14
MARKET	OEM	OEM	OEM	OEM	OEM
MEDIA: Nominal disk diameter	3.5"	3.5"	3.5"	3.5"	3.5"
Recording medium	High Density Oxide Coated	High Density Oxide Coated	High Density Oxide Coated	High Density Oxide Coated	High Density Oxide Coated
CAPACITY/RECORDING DENSITY					
Total capacity (Mbytes)	F: .7/1.2/1.4	F: .7/1.2	F: .7/1.2	F: .7/1.4	F: .7/1.2/1.4
Capacity per track (Bytes)	F: 4,608/9,216	F: 4,608/7,680	F: 4,608/7,680	F: 4,608/9,216	F: 4,608/9,216
Data surfaces per spindle	2	2	2	2	2
Tracks per surface	80	80	80	80	80
Track density (TPI)	135	135	135	135	135
Maximum linear density (BPI)	8717/17434	8717/14528	8717/14528	8717/17434	8717/17434
Recording code	MFM	MFM	MFM	MFM	MFM
Rotational speed (RPM)	300/360	300/360	300/360	300	300/360
PERFORMANCE					
Actuator type	Lead Screw, Stepping Motor	Lead Screw, Stepping Motor	Lead Screw, Stepping Motor	Lead Screw, Stepping Motor	Lead Screw, Stepping Motor
POSITIONING: Track to track (msec)	3	3	3	3	3
Settling time (msec)	15	15	15	15	15
Average rotational delay (msec)	100	100/83.3	100/83.3	100	100
Data transfer rate (KBytes/sec)	31.25/62.5	31.25/62.5	31.25/62.5	31.25/62.5	31.25/62.5
SIZE (mm: H x W x D)	21.0 x 104.0 x 160.0	25.4 x 101.6 x 145	41.9 x 104.1 x 161.8	25.4 x 101.6 x 145	25.4 x 101.6 x 145
FIRST CUSTOMER SHIPMENT	2Q99	2Q88	2Q88	2Q88	
COMMENTS	USB interface.		SCSI interface.		

MANUFACTURER	TEAC	Y-E DATA	Y-E DATA	Y-E DATA	Y-E DATA
DRIVE	FD-235HS	YD-180	YD-380B-1710B	YD-380B-1714B	YD-380B-1734H
DISK/TREND GROUP	14	14	14	14	14
MARKET	OEM	OEM	OEM	OEM	OEM
MEDIA: Nominal disk diameter	3.5"	8"	5.25"	5.25"	5.25"
Recording medium	High Density Oxide Coated	Oxide Coated	High Density Oxide Coated	High Density Oxide Coated	High Density Oxide Coated
CAPACITY/RECORDING DENSITY					
Total capacity (Mbytes)	F: .7/1.4	F: .6/1.2	F: 1.2	F: .7/1.2	F: .7/1.2
Capacity per track (Bytes)	F: 4,608/9,216	F: 4,096/8,192	F: 7,680	F: 4,608/7,680	F: 4,608/7,680
Data surfaces per spindle	2	2	2	2	2
Tracks per surface	80	77	77	80/77	80
Track density (TPI)	135	48	96	96	96
Maximum linear density (BPI)	8717/17434	3408/6816	9646	5922/9646	5922/9870
Recording code	MFM	MFM	MFM	MFM	MFM
Rotational speed (RPM)	300	360	360	300/360	600/720
PERFORMANCE					
Actuator type	Lead Screw, Stepping Motor	Band, Stepping Motor	Band, Stepping Motor	Band, Stepping Motor	Band, Stepping Motor
POSITIONING: Track to track(msec)	3	3	3	3	3
Settling time (msec)	15	15	15	15	15
Average rotational delay (msec)	100	83.3	83.3	100/83.3	50/41.6
Data transfer rate (KBytes/sec)	31.25/62.5	31.25/62.5	62.5	31.25/62.5	75/125
SIZE (mm: H x W x D)	41.9 x 104.1 x 161.8	57.2 x 217.2 x 320	41.3 x 146 x 203.2	41.3 x 146 x 203.2	41.3 x 146 x 203.2
FIRST CUSTOMER SHIPMENT	1990	9/81	4/86	4/86	6/90
COMMENTS	SCSI interface.				Double speed drive sold for duplicators.

MANUFACTURER	Y-E DATA	Y-E DATA	Y-E DATA	Y-E DATA	Y-E DATA
DRIVE	YD-380B-1734S	YD-801 YD-802	8U10-83000 8U00-01000 FlashBuster-U	8U00-80010 FlashBuster-U for iMac	YD-686C
DISK/TREND GROUP	14	14	14	14	14
MARKET	OEM	OEM	OEM	OEM	OEM
MEDIA: Nominal disk diameter	5.25"	5.25"	3.5"	3.5"	3.5"
Recording medium	High Density Oxide Coated	High Density Oxide Coated	High Density Oxide Coated	High Density Oxide Coated	High Density Oxide Coated
CAPACITY/RECORDING DENSITY					
Total capacity (Mbytes)	F: .7/1.2	F: 1.2/2.4	F: .7/1.2/1.4	F: .7/1.4	F: .7/1.2
Capacity per track (Bytes)	F: 4,608/7,680	F: 20,832	F: 4,608/7,680 9,216	F: 4,608/9,216	F: 4,608/7,680
Data surfaces per spindle	2	2	2	2	2
Tracks per surface	80/77	80	80/77/80	80/80	80/77
Track density (TPI)	96	96	135	135	135
Maximum linear density (BPI)	5922/9870	19740	8717/14184/ 17434	8717/17434	8717/14184
Recording code	MFM	MFM	MFM	MFM	MFM
Rotational speed (RPM)	600/720	180/360	300/360/300	300/300	300/360
PERFORMANCE					
Actuator type	Band, Stepping Motor	Band, Stepping Motor	Lead Screw, Stepping Motor	Lead Screw, Stepping Motor	Lead Screw, Stepping Motor
POSITIONING: Track to track(msec)	3	3	3	3	3
Settling time (msec)	15	15	15	15	15
Average rotational delay (msec)	50/41.6	166.7	100/83.3/100	100/100	100/83.3
Data transfer rate (KBytes/sec)	75/125	62.5	31.25/62.5/62.5	31.25/62.5	31.25/62.5
SIZE (mm: H x W x D)	41.3 x 146 x 203.2	41.3 x 146 x 203.2	23.6 x 103.5 x 154.5	23.6 x 103.5 x 154.5	25.4 x 101.6 x 149.9
FIRST CUSTOMER SHIPMENT	6/91	1Q87	4Q98	3Q98	1Q87
COMMENTS	Double speed R/W drive sold for duplicators	Compatible with 1.0 and 1.6 MB formats.	External drive with USB interface.	External drive with USB interface for iMac.	

MANUFACTURER	Y-E DATA	Y-E DATA	Y-E DATA	Y-E DATA	Y-E DATA
DRIVE	YD-701B YD-702B YD-702D	YD-701B-6336H	YD-701B-6331S	YD-701B-6431H	FlashBuster 3
DISK/TREND GROUP	14	14	14	14	14
MARKET	OEM	OEM	OEM	OEM	OEM
MEDIA: Nominal disk diameter	3.5"	3.5"	3.5"	3.5"	3.5"
Recording medium	High Density Oxide Coated	High Density Oxide Coated	High Density Oxide Coated	High Density Oxide Coated	High Density Oxide Coated
CAPACITY/RECORDING DENSITY					
Total capacity (Mbytes)	F: .7/1.2/1.4	F: .7/1.2/1.4	F: .7/1.2/1.4	F: .7/1.2/1.4	F: .7/1.2/1.4
Capacity per track (Bytes)	F: 4,608/7,680 9,216	F: 4,608/7,680 9,216	F: 4,608/7,680 9,216	F: 4,608/7,680 9,216	F: 4,608/7,680 9,216
Data surfaces per spindle	2	2	2	2	2
Tracks per surface	80/77/80	80/77/80	80/77/80	80/77/80	80/77/80
Track density (TPI)	135	135	135	135	135
Maximum linear density (BPI)	8717/14184/ 17434	8717/14184/ 17434	8717/14184/ 17434	8717/14184/ 17434	8717/14184/ 17434
Recording code	MFM	MFM	MFM	MFM	MFM
Rotational speed (RPM)	300/360	600/720/600	600/720/600	1200/1440/1200	300/360/300
PERFORMANCE					
Actuator type	Lead Screw, Stepping Motor	Lead Screw, Stepping Motor	Lead Screw, Stepping Motor	Lead Screw, Stepping Motor	Lead Screw, Stepping Motor
POSITIONING: Track to track(msec)	3	3	3	3	3
Settling time (msec)	15	15	15	15	15
Average rotational delay (msec)	100	50/41.6/50	50/41.6/50	25/20.8/25	100/83.3/100
Data transfer rate (KBytes/sec)	31.25/62.5/62.5	62.5/125/125	62.5/125/125	125/250/250	31.25/62.5/62.5
SIZE (mm: H x W x D)	25.4 x 101.6 x 149.9	25.4 x 101.6 x 149.9	25.4 x 101.6 x 149.9	25.4 x 101.6 x 149.9	23.6 x 103.5 x 154.5
FIRST CUSTOMER SHIPMENT	1Q87	2Q95	2Q95	3Q95	
COMMENTS		Doublespeed drive sold for duplicators	Doublespeed R/W drive sold for duplicators	Quadspeed drive sold for duplicators	External drive with PC card interface.

MANUFACTURER	Y-E DATA	Y-E DATA	Y-E DATA		
DRIVE	YD-701B-6431S	YD-702J	YD-702D		
DISK/TREND GROUP	14	14	14		
MARKET	OEM	OEM	OEM		
MEDIA: Nominal disk diameter	3.5"	3.5"	3.5"		
Recording medium	High Density Oxide Coated	High Density Oxide Coated	High Density Oxide Coated		
CAPACITY/RECORDING DENSITY					
Total capacity (Mbytes)	F: .7/1.2/1.4	F: .7/1.2/1.4	F: .7/1.4		
Capacity per track (Bytes)	F: 4,608/7,680 9,216	F: 4,608/7,680 9,216	F: 4,608/9,216		
Data surfaces per spindle	2	2	2		
Tracks per surface	80/77/80	80/77/80	80/80		
Track density (TPI)	135	135	135		
Maximum linear density (BPI)	8717/14184/ 17434	8717/14184/ 17434	8717/17434		
Recording code	MFM	MFM	MFM		
Rotational speed (RPM)	1200/1440/1200	300/360/300	300		
PERFORMANCE					
Actuator type	Lead Screw, Stepping Motor	Lead Screw, Stepping Motor	Lead Screw, Stepping Motor		
POSITIONING: Track to track(msec)	3	3	3		
Settling time (msec)	15	15	15		
Average rotational delay (msec)	25/20.8/25	100/83.3/100	100/100		
Data transfer rate (KBytes/sec)	125/250/250	31.25/62.5/62.5	31.25/62.5		
SIZE (mm: H x W x D)	25.4 x 101.6 x 149.9	12.7 x 96 x 129.5	25.4 x 101.6 x 149.0		
FIRST CUSTOMER SHIPMENT	3Q95	2Q94			
COMMENTS	Quadspeed R/W drive sold for duplicators				

MANUFACTURER PROFILES

All manufacturers now producing optical or removable disk drives, or those companies that are expected to enter the market, are listed in this section. DISK/TREND normally estimates the annual volume of disk drive sales by manufacturers. Because not all companies had a relatively high level of disk drive sales, this figure is reported explicitly only for firms with major 1998 optical or removable disk sales. "1998 total net sales" covers the fiscal year ending in 1998 for each manufacturer unless noted otherwise, or for the parent company if the manufacturer is a subsidiary. All fiscal years end on December 31, 1998, unless otherwise noted.

Manufacturers located in the United States that have majority owners headquartered in other countries are grouped in the geographical area in which the owner's home office is located.

Exchange rates

The exchange rates used in converting the financial data of non-U.S. manufacturers to dollars are given below. The average exchange rates for 1998 are used, as reported by the U.S. Federal Reserve Bulletin.

Country	Currency	Currency Units/U.S. dollar
Canada	Canadian dollar	1.48
France	French franc	5.90
Germany	Deutschmark	1.76
Hong Kong	Hong Kong dollar	7.75
Japan	Yen	131.0
Malaysia	Ringgit	3.93
Netherlands	Guilder	1.98
Singapore	Singapore dollar	1.67
South Korea	Won	1400.4
Taiwan	Taiwan dollar	33.55
United Kingdom	Pound	0.6

Use caution in making year to year comparisons of sales revenue and income figures, as they are significantly impacted by exchange rate changes.

U.S. Manufacturers

AVATAR PERIPHERALS, INC.
1455 McCarthy Boulevard
Milpitas, CA 95035

Avatar was founded in 1991 as Avatar Systems by John Bizjak, a veteran of several pioneering disk drive programs, to develop high capacity disk cartridge drives. The company started production of an 85 megabyte 2.5" disk cartridge drive in mid-1993, using glass disks, and intended for portable and desktop applications. After management changes in 1994, emphasis was placed on 170 megabyte drive models primarily for OEM markets. After more management changes in 1996 and a name change to Avatar Peripherals, emphasis was placed on 250 megabyte drive models targeted at distribution markets. Drive development centered in Milpitas, using a manufacturing facility established in Thailand in 1995. By early 1999, it had become clear that the emphasis on distribution markets was not paying off, and Avatar's operations were closed down.

CALEB TECHNOLOGY CORPORATION
4775 Walnut Street
Boulder, CO 80301

Caleb was founded in 1995 by one of the key managers from the Iomega drive development program in Boulder, with extensive experience in optical and magnetic disk drives. The company originally planned to develop and manufacture a 200 megabyte floppy drive, but after the departure of the founder and acquisition of a major interest by Kabool Electronics, a part of the South Korean Kabool textiles group, the company announced a backward compatible 144 megabyte 3.5" drive in 1997. The firm is working on an additional round of financing, and currently plans to initiate drive production through a contract manufacturing arrangement in Singapore.

CASTLEWOOD SYSTEMS
5000 Hopyard Road, Suite 330
Pleasanton, CA 94588

Castlewood Systems was founded in September, 1996, by Syed Iftikar, former founder and CEO of SyQuest Technology, and announced a 2.16 gigabyte 3.5" disk cartridge drive using a single disk cartridge at the 1997 Fall Comdex show. Castlewood has arranged with two Malaysian companies to manufacture the drives on a contract basis, and a similar arrangement for disk cartridges has been made with a Taiwan firm. Volume deliveries were started in early 1999.

CD-ROM, INC.
1301 Arapahoe Street, Suite 7
Golden, CO 80401

CD-ROM, founded in 1988, is a U.S. owned and headquartered manufacturer of CD-ROM drives (using purchased mechanisms). The firm sells mostly to the U.S. government, although there are significant international sales. CD-ROM, Inc. is also known as a distributor of other CD-ROM drives, tower assemblies, disks and related products. The company also welcomes customized drive design and consulting assignments.

DIGITAL VIDEO SYSTEMS
280 Hope Street
Mountain View, CA 94041

Founded in 1992, DVS acquired the DVD-ROM business of Hyundai in May, 1998. The company established a subsidiary, DVS Korea, to oversee the manufacturing of the disk drives on a contract manufacturing basis. The company anticipates developing OEM relationships with major Korean system manufacturers.

EASTMAN KODAK COMPANY
343 State Street
Rochester, NY 14650

1998 total net sales: $13,406,000,000 Net income: $1,390,000,000

Eastman Kodak has had two publicly announced optical disk drive production efforts, one a very high capacity 14" write-once optical disk drive and the other a low-end 3.5" magneto-optical drive. The latter product originated at Verbatim Corporation, acquired by Eastman Kodak in 1985. In 1989, Eastman Kodak purchased a 40% ownership in Laserdrive and transferred the 3.5" drive development to Laserdrive. Laserdrive was merged into the now defunct Literal Corporation, in which Eastman Kodak had a 26% interest, in 1990. Verbatim, sold to Mitsubishi Kasei in 1990, continued optical media and head development.

The Eastman Kodak Photo CD system, which permits photo processing centers to transfer photographic images to write-once CD disks, began shipping in the last half of 1992. CD-ROM players, operating as part of a CD-I system, are supplied by Philips to attach to consumer TV sets for playback of the images. Philips is also supplying the CD recorders used by participating photo processors, although Kodak produced its own 6X CD-R drive (Kodak also provides the media) using a purchased mechanism until 1998. Kodak expanded the role of the Photo CD products to include recording and distribution of other types of data, and is marketing software enabling use of Photo CD images and other types of files with IBM compatible personal computers. The firm also manufactures CD-R media.

The 14" drive began its production run in 1987, but production has been modest. It uses a zoned format and employs proprietary dye-polymer media. A 7.4 gigabyte per side version was announced in 1994. The drive was used in Eastman Kodak's image storage product lines and also offered on an OEM basis as a computer peripheral. The firm introduced a two headed drive with 25 gigabyte capacity per disk in mid-1996 for shipment in mid-1997, subsequently slipped to mid-1998. The drive was able to read earlier Kodak 14" media. However, in early 1998, Eastman Kodak announced it planned to withdraw from the 14" drive business in early 1999. Media production continues through 2002.

Eastman Kodak produces automated library units for use with it own 14" drive, but discontinued a 5.25" library for use with purchased drives. The 14" libraries are also sold on an OEM basis. The firm also purchases library units for systems using 12" drives from other manufacturers. CD-ROM libraries are also sold by Eastman Kodak, with an internally manufactured unit displayed at the 1997 AIIM conference.

HALO DATA DEVICES
1140 Ringwood Court
San Jose, CA 95131

Founded in March of 1998, Halo is developing a 3.3 millimeter low profile rigid disk drive based on technology acquired from the now-defunct ThinSpin LLD. The drive will use the CompactFlash Card Type II format, and target specifications are 265 megabytes capacity and 5,400 RPM rotation rate, using a single recording head. Like the CompactFlash Card, it will operate at 3.3 volts, but may draw about .25 amperes at spin-up.

HEWLETT-PACKARD COMPANY
3000 Hanover Street
Palo Alto, CA 94303

1998 total net sales: $47,061,000,000 (FY ending 10/31/98)   Net income: $2,945,000,000

In 1989, H-P announced that it would sell the Sony 5.25" rewritable drive as an OEM or end user system peripheral in both stand-alone and jukebox configurations. Hewlett-Packard then announced its own high performance 5.25" magneto-optic disk drive, code named Corsair, in 1991, for volume delivery in 1992. The drives were produced in the Greeley, Colorado, facility, which has also produced optical libraries since 1989. A double capacity drive with 650 megabytes per side capacity, the Corsair II, was announced at the 1993 AIIM conference. It went into production in 1993, using a mechanism made by a contract manufacturer.

Despite large increases in production, Hewlett-Packard moved towards a view of internal optical drive manufacturing as nonstrategic and halted optical drive production in 1996, becoming a drive purchaser for future generations of drives. The company is also a major reseller of CD-RW drives based on Sony mechanisms.

H-P remains the leading revenue producer in the 5.25" optical library market, with a product line spanning the range from 16 to 144 cartridge capacities. The libraries are used in H-P systems, and while H-P also sells them to OEM accounts, the firm emphasizes sales through distributors. The firm is also a major supplier of CD-ROM towers and other storage subsystems.

IMATION CORPORATION
1 Imation Place
Oakdale, MN 55128

1998 total net sales: $2,046,500,000 Net income: $57,100,000

Imation was created in 1996, as a spin-off of the 3M data storage and imaging businesses. The company's data storage products include magnetic tape, optical disk media, standard diskettes and the LS-120 program, subsequently renamed SuperDisk, which includes media and drives. Imation has undertaken an extensive program to expand distribution of LS-120 drives which it obtains on a contract manufacturing basis from other companies active in the LS-120 group. Both drives and media have been featured in an extensive Imation advertising program undertaken to create awareness of the group's adoption of the brand name "SuperDisk". Imation also actively remarkets CD-RW drives and media.

INTEGRAL PERIPHERALS
5775 Flatiron Parkway
Boulder, CO 80301

Integral Peripherals was founded in September, 1990, by engineering and management personnel who previously pioneered early 2.5" drives at PrairieTek. The company was the first to design and manufacture 1.8" disk drives. Its initial product was a 20 megabyte drive, first produced in the second half of 1991, and for which the available market was minimal. Integral had somewhat better luck with a 42 megabyte model placed in production in early 1992, and a succession of higher capacity models which followed. Integral's 1.8" drives used ramp loaded heads, and were designed to high operating shock and vibration specifications, with low power requirements, in anticipation of wide usage in subnotebook computers and other mobile computer applications.

Integral pioneered in utilizing untextured disks in higher capacity models, a technique made possible by using the ramp loading head method to avoid parking heads on the disk surface. Integral began its high volume manufacturing in Singapore in mid-1992, moved into a new plant in 1995 and added 1.8" drives with up to 340 megabytes all in PC Card Type III format, with a 510 megabyte model announced but never produced. In 1995, Integral added 2.5" drives as the beginning of a new product family, the result of a design contract with Samsung Electronics to provide designs for 2.5" drives, with both companies entitled to manufacture the drives involved.

After finding a cool market reception for latecomers to the 2.5" disk drive business, Integral switched to 3" drives in 1997. The combination of the limited market available for 1.8" drives, the firm's expenditures to develop and initiate production of 2.5" and 3" drives, and the withdrawal from the market of other announced 3" drive producers finally became too big a burden on Integral's finances, and the company entered U.S. Chapter 11 bankruptcy proceedings. Attempts were made to secure new financing and complete the design for a higher capacity 3" mobile disk drive, while abandoning the 1.8" drives which had been the company's core product line. Hambrecht & Quist acquired Integral's assets from bankruptcy and the reborn company will concentrate on small fixed disk drives for the mobile computer market.

INTERNATIONAL BUSINESS MACHINES CORPORATION
Route 22
Armonk, NY 10504

1998 total net sales: $81,667,000,000 Net income: $6,328,000,000

IBM started slowly in the optical storage area, but eventually manufactured or remarketed a variety of products, including CD-ROMs, write-once and erasable drives and optical libraries. While not currently manufacturing any optical drives or libraries, IBM remains a very active participant in the optical drive and media standards committees and has played an important role in resolving industry conflicts regarding DVD drives. IBM currently relies on outside purchases of CD-ROM and other CD format drives and is judged unlikely to manufacture its own CD-ROM drives, but is actively involved in the design of systems using multimedia techniques involving a variety of optical drive types, including CD/DVD-ROM and magneto-optic drives. IBM also produces the MicroDrive, a 1" diameter rigid disk drive packaged in a CompactFlash Card Type II 5 millimeter thick package, which was formally announced as a production product in mid-1999.

In the beginning of 1995, IBM completed a review of all of its product lines to determine which met its criteria for long-range commitment of investments. The optical drive activity did not meet IBM's internal criteria, and IBM shut down its optical drive production, selling its existing inventories at bargain prices to OEMs and resellers and ceasing use of its own drives in libraries in late 1996. The firm has since found an alternative manufacturing source for its multifunction 5.25" drive, which is still required by some customers.

IOMEGA CORPORATION
1821 West Iomega Way
Roy, UT 84067

1998 total net sales: $1,694,385,000 Net income: ($54,222,000)

Iomega, founded in 1980, was successful in establishing production capability for its unique 8" flexible disk drive, which maintained control of head/disk contact with the Bernoulli effect. The product was originally intended as an OEM drive, but Iomega had much better luck with subsystems sold in the personal computer add-on market. The original 8" drives for the IBM PC market provided most of the company's revenue growth until displaced by the 5.25" models in production from 1987 to 1996. But time passes on, and the Bernoulli drive product line is now out of production, and Iomega moved on to new products with much larger markets.

Attempting to broaden its product coverage, Iomega licensed the Insite Peripherals "floptical" drive and media. Iomega's 20 megabyte "floptical" drive was introduced in 1992, but was discontinued in 1994 after only limited sales success. That venture convinced Iomega's management that a comparable drive with higher capacity and the right price could be a success. The result was the 100 megabyte "Zip" 3.5" floppy drive, which began shipments in early 1995, and has found a much broader market, due to its unique combination of 100 megabyte disk capacity and initial $199 drive retail price, since reduced. The 250 megabyte version subsequently introduced restored the $199 price level. The intensive advertising campaign waged by Iomega created high visibility for the Zip drive in the aftermarket and was a major factor in the establishment of the Zip as a standard peripheral option in the product lines of several PC producers.

The 1 gigabyte two platter "Jaz" drive, which first shipped in late 1995, marked Iomega's entry into the rigid cartridge disk drive market. The Jaz was produced for Iomega under contract by Sequel until the Autumn of 1996, when Iomega moved manufacturing to its own factory in Penang. The factory was purchased in 1996 from Quantum, when that company discontinued internal manufacturing of high-end rigid disk drives. The 2 gigabyte Jaz 2 drive started shipments in the first quarter of 1998. When SyQuest ceased operations in late 1998, Iomega moved to purchase the SyQuest inventory and other assets, and has arranged with Peripheral Computer Support (PCS) to sell the remaining SyQuest inventory and provide technical support.

In mid-1999, Iomega began marketing CD-RW drives and media, based upon drives purchased from other manufacturers.

MAXOPTIX CORPORATION
2520 Junction Avenue
San Jose, CA 95134

Maxoptix began in 1986 as a research program within Maxtor Corporation. In March of 1989, Maxtor and Kubota, Ltd. formed Maxoptix, a joint venture 63% owned by Maxtor. The first 5.25" MO drives produced by Maxoptix were shipped in 1990. Kubota purchased Maxtor's share in early 1995. Maxoptix designed and marketed rewritable optical disk drives manufactured by Kubota. Kubota has worldwide manufacturing rights and exclusive sales rights in Japan for Maxoptix products. In late 1997, Maxoptix became an independent company again as a result of a management buyout, but the firm retained strong links with Kubota, continuing to resell Kubota's 5.25" optical libraries. Maxoptix has historically followed a strategy of emphasizing leading edge performance and capacity, as well as increasing the functional capabilities of its optical drives with each new product introduction, but its current strategy includes optical subsystem integration and reduces the firm's reliance upon drive sales for growth.

In 1999, Maxoptix announced and demonstrated technology directed at the production of a 20 gigabyte per side optical drive, currently scheduled for production in mid-2000.

MOUNTAIN OPTECH, INC.
4775 Walnut Street
Boulder, CO 80301

Mountain Optech, founded in 1985, specializes in optical disk drives for ruggedized and military applications. Its first product was a modified version of the Optotech 5.25" write-once drive, delivered in 1986. The modified drives, which now include 3.5" and CD format models, are used in harsh environments such as seismic survey, aircraft maintenance, and manned spacecraft. The mechanism and electronics have been modified for ruggedized or militarized requirements. Current products emphasize fast MO drives using Maxoptix mechanisms.

PERIPHERAL COMPUTER SUPPORT, INC.
44131 Nobel Drive
Fremont, CA 94538

PCS, Inc., is an established supplier of service management and limited production for disk drives and other computer peripherals. The company maintains facilities in California, Asia and Europe, and in mid-1998 acquired the Singapore facility in which Integral Peripherals had previously manufactured disk drives. Calluna Technology has announced a deal with PCS to provide contract manufacturing services for the Calluna Type II PC Card drive. PCS has also been licensed to manufacture and sell the 1.8" drives manufactured by Integral Peripherals before that firm filed bankruptcy and is expected to also arrange for manufacturing of disk cartridge drives no longer in production.

PINNACLE MICRO
140 Technology Drive
Irvine, CA 92618

1997 total net sales: $31,124,000 (FY ending 12/27/97) Net income: ($30,229,000)

Pinnacle Micro, founded in 1987, started as a subsystem producer and remarketer of optical drives and libraries, but in 1992 the firm began assembling 5.25" rewritable drives using purchased mechanisms and internally supplied electronics. The firm established a development center for optical products in Colorado Springs in 1993. Pinnacle Micro had started an optical drive factory, also in Colorado Springs, to produce complete high performance, high capacity 5.25" magneto-optical drives and other products, but shut this facility in 1997 due to financial reverses, and returned production to California. In addition to MO drives, Pinnacle Micro sells optical libraries using HP jukebox mechanisms and equipped with its own drives. The firm also remarkets CD-R and CD-RW drives.

In 1994, Pinnacle Micro introduced the Orray, an array of 5.25" optical drives with a controller that operated them concurrently, but did not develop a significant market for it. In 1995, the firm announced a non-ISO standard drive, the Apex 4.6 gigabyte MO drive. While unable to put it into production at that time, the firm was able to begin shipments in late 1996 after a major management change. The Apex drive's high capacity, coupled with an unusually low OEM selling price, stimulated substantial initial customer interest, but high volume shipments did not materialize. The Vertex, a more conventional 2.6 gigabyte drive, that went into production in mid-1996, was displaced by the Ultra 5.2 gigabyte drive in 1998. The Ultra drive is based on a purchased mechanism.

QUINTA CORPORATION (Subsidiary of Seagate Technology)
1870 Lundy Drive
San Jose, CA 95131

Quinta, founded by several executives from the disk drive industry, originated as a U.S. start-up corporation planning to develop high capacity, high performance optical disk drives. Relatively little information about its specific target products was announced by Quinta, but in July, 1997, Seagate announced it was acquiring Quinta for a minimum of 230 million dollars. Quinta was subsequently folded into the Seagate corporate structure and now operates as a development center specializing in optical technology development, rather than specific product development, spinning off its OAW (Optically Assisted Winchester) technology to Seagate's advanced development centers for use in future drive designs.

SIERRA TECHNOLOGIES CORPORATION
2938 Janitell Road
Colorado Springs, CO 80906

Founded in November, 1993, by former employees of defunct Literal Corporation, Sierra is doing end-of-life assembly of drives and media inherited from Literal and its licensee, Maximum Storage. A very limited supply of new drives is available to existing customers, but media is plentiful. In addition, the firm remarkets high capacity drives from Matsushita Electric, and is slowly converting the old Literal customer base to the MEI phase change media based product line.

SIROS TECHNOLOGIES, INC.
101 Daggett Drive
San Jose, CA 95134

Siros Technologies, founded in 1994, was originally known as Optitek. The company was initially funded by research grants from the U.S. government, enabling Optitek to participate in two industry consortia working on storage products based upon holographic recording technology. Optitek changed its name to Siros Technologies in 1998, after an infusion of new management, new investment, and a change in direction, and began developing an optical disk drive.

The Siros 3DR (for three dimensional recording) drive currently under development is a removable media write-once drive based upon previous work in multi-surface recording and playback. Development is being done with other partners active in the optical drive industry. Future drive development will incorporate recording technology acquired from Lucent Technologies, which obtained a substantial equity position in Siros in exchange for exclusive optical technology rights, cash and equipment. The Lucent VSAL (Very Small Aperture Laser) recording technology (originally developed at Bell Laboratories) employs a very small slider mounted laser to produce very small spot sizes. An effective aperture of 50 nanometers has been previously demonstrated.

The Siros VSAL drive, which is expected to store well in excess of 50 gigabytes per side on a 5.25" disk and eventually reach an areal density approximating 200 gigabits per square inch, is in the early development phase, with no production date or specifications yet established. The 3DR drive might appear as early as 2000, but there has been no announcement of a schedule, other than an intention to demonstrate the 3DR technology sometime in 1999.

SWAN INSTRUMENTS
100 Great Oaks Boulevard
San Jose, CA 95119

Swan Instruments was founded in 1984 as a producer of rigid disk drive head testing instruments and fixtures, but the company transitioned into the high capacity floppy drive business. For several years, it attempted to develop a market for high capacity flexible disk drives, and in 1994 announced a high capacity floppy disk drive in a 3.5" form factor, with the combination of fixed and removable metal powder flexible disks. Swan had licensed technology for high capacity floppy drives previously developed by Antek Peripherals, and which was subsequently also licensed to Mitsumi Electric. After a prolonged legal contest, a truce was signed, with an agreement giving both Mitsumi and Swan the right to manufacture the drives, and a plan to cooperate in setting up manufacturing arrangements for disk cartridges. The 130 megabyte 3.5" drive announced by both companies was to be backward compatible with 1.44 megabyte standard 3.5" diskettes, but the start of drive shipments originally expected in 1997 never commenced. Swan also developed a special version of the drive to be produced on a contract basis for Sega in 1999. However, neither Mitsumi or Swan ever managed to complete the arrangements for manufacturing either drives or disk media, and Swan went out of business in 1998.

SYQUEST TECHNOLOGY
47071 Bayside Parkway
Fremont, CA 94538

SyQuest was started in early 1982 to make rigid disk drives using 3.9" (100 mm) plated disks, in both fixed and removable disk cartridge configurations, but after several years of production 3.9" disks were displaced by industry standard sizes. The firm began shipping 5.25" disk cartridge drives with formatted capacity of 44 megabytes and embedded SCSI controllers in 1988, achieving significant success in the Macintosh add-on market, and with its 5.25" disk cartridges, eventually becoming the dominant "prepress" interchange standard for graphics and desktop publishing. In 1989, SyQuest began manufacturing in Singapore.

In the 1990's, SyQuest increased the capacity of its 5.25" cartridge disk drive series to 88 megabytes, then to 200 megabytes. A 3.5" disk cartridge drive program resulted in first shipments of 105 and 270 megabyte models in 1993. SyQuest also manufactures the disk cartridges for the drives, and cartridges account for about half of the firm's revenue. A unique 1.8" drive was announced in 1995, utilizing a disk cartridge designed to be removable from a PC Card Type III disk drive, but the project was stopped in early 1996.

The EZ135, a 135 megabyte drive marketed as a counter to the high capacity floppy Iomega "Zip" drive, began shipping in mid-1995, but the product was a major financial drain and production was stopped in mid-1996. SyQuest suffered financial difficulties from mid-1995, as the result of costs which were higher than expected for the EZ135, combined with significant penetration of traditional SyQuest markets by both the Iomega Zip drive and the Jaz rigid disk cartridge drive series.

As the result of the company's continuing financial losses, a major management reorganization was undertaken, 60% of the company's employees were laid off, and the company's activities were refocused on new products. The 230 megabyte EZFlyer 3.5" drive replaced the money losing EZ135. The two platter 1.5 gigabyte SyJet 3.5" disk cartridge drive went into production in early 1997 and the single platter 1 gigabyte SparQ 3.5" disk cartridge drive started production at the end of 1997, both with the mission to reclaim the high-end disk cartridge market from the Iomega Jaz.

Despite intense market development programs, aggressive pricing and expanded production facilities, SyQuest wasn't able to turn the business around, and most of its operations were closed down in November, 1998. During the subsequent bankruptcy proceedings, Iomega purchased all of SyQuest's intellectual property, U.S. fixed assets and inventory, and the remaining service and warranty business is continuing under the name SYQT, Inc.

TERASTOR CORPORATION
2310 North 1st Street
San Jose, CA 95131

Founded in 1996 by several disk drive industry veterans, TeraStor is developing a high capacity, high performance optical disk drive employing "near field recording" technology. The company intends to license other firms to manufacture drives using its technology, and licensed Quantum to manufacture drives in 1997. TeraStor is combining rigid disk drive technology with optical recording technology originally developed by DEC (and subsequently acquired by Quantum, a minority shareholder in the firm) and immersion lens technology developed at Stanford. TeraStor's goal is a drive with areal density exceeding rigid drive areal density by a factor of 10 and having near rigid drive performance.

Strategic partners include Imation for media, SSI for chips, Mitsumi for manufacturing and Yamaha (originally Seagate) for heads.

TeraStor currently expects to ship 10 and 20 gigabyte drives in 1999, a schedule significantly delayed from original plans. The firm has attracted a great deal of industry interest and, if successful, could have a major impact on the removable data storage industry, impacting manufacturers of rigid removable drives, optical drives and tape drives.

Asian Manufacturers

(All fiscal years end in March, 1999, unless otherwise noted. All companies are in Japan unless otherwise noted.)

ACER PERIPHERALS
157 Shan Ying Road
Kweishan, Taoyuan 333
Taiwan

Acer Peripherals (API) was started by Acer, Inc., in 1984. The company produces keyboards, fax machines, printers, monitors and CD-ROM drives, which are based upon Philips mechanisms. The company expanded CD-ROM production and moved to larger facilities in 1995, becoming one of Taiwan's largest producers of CD-ROM drives. API also produces CD-RW and DVD-ROM drives.

ACTIMA TECHNOLOGY CORPORATION
12F, No. 2, Wu-Ling Road
Hsinchu 300
Taiwan

Actima, founded in May of 1997, is part of the Chang Gu Group, a conglomerate active in building and construction. Actima was started as part of a group-wide diversification program, and currently manufactures CD-ROM drives. The firm's first product was a 24X drive, introduced in early 1998, followed by models with speeds to 50X. DVD-ROM and CD-RW drives were introduced in late 1998.

AFREEY INC.
3F, 102 Sung Lung Road
Taipei
Taiwan

Afreey was founded in April, 1998. The company manufactures high performance CD-ROM and DVD-ROM drives, including significant portions of the drive mechanism. Production is at the firm's factory in Chung Ho, Taiwan.

AOPEN (Acer, Inc.)
88, Section 1, Hsin Tai Wu Road
Hsi Chih, Taipei Hsien 221
Taiwan

Acer was founded as Multitech International in 1976, and after a period of growth changed its name to Acer for improved recognition. The company is Taiwan's largest producer of personal computers. The company also produces its own drives, based upon purchased mechanisms, although it has future plans to develop its own mechanisms. The company formed Advanced Information as a separate business unit for its AOpen brand name products in 1997, later converting to AOpen as the business unit name. The product line includes CD-ROM, DVD-ROM and CD-RW drives.

ALPS ELECTRIC CO., LTD.
1-7, Yukigaya Otsuka-cho
Ohta-ku, Tokyo 145

1998 total net sales: $4,171,214,000 Net income: $46,689,000

Alps Electric is a major manufacturer of electronic components and subassemblies for audio, television, instrument and computer applications. Peripheral devices, including printers and floppy disk drives, accounted for 25% of revenues during the last year. Alps supplies components to other companies wishing to make CD-ROMs and can supply design assistance and components, or will manufacture on a contract basis. In 1994, the firm began to market CD-ROM drives under its own name, but subsequently withdrew its branded CD-ROM drive products, except for small CD-ROM autochangers that began shipments in 1996. Shipments of CD-ROM drive mechanisms continue, but the autochanger has also been discontinued.

The firm's initial surge in floppy drive shipments came in 1981, with a rapid buildup of shipments to Apple Computer. In the Spring of 1987, Alps became the first Japanese company to manufacture floppy drives in the U.S., with 5.25" drives made in Garden Grove, California. Alps has also manufactured floppy drives in Ireland. Alps began shipping 3.5" microfloppy drives in mid-1984. A prototype 2.5" nonremovable floppy disk drive with a 10 megabyte capacity and average seek time of 50 milliseconds was shown to prospective customers in 1991 but was not formally announced. Alps has been licensed by Sony to make the HiFD 200 megabyte floppy drive, and plans to start production following Sony's reintroduction of the HiFD later in 1999.

ASUSTEK COMPUTER, INC.
150 Li-Te Road, Peitou
Taipei
Taiwan

A computer maker that entered the CD-ROM manufacturing arena in 1997, the firm introduced a 34X CD-ROM drive in 1998, the only one of its type. The firm has since introduced a 40X model.

BEHAVIOR TECH COMPUTER CORPORATION
12/F, No. 18, Section 1
Chang An East Road
Taipei
Taiwan

Established in February, 1982, BTC is a manufacturer of computer components such as keyboards, mice, trackballs, power supplies and various cards. CD-ROM drives (using purchased mechanisms) were added to the product line in 1994. The company produces CD-ROM, CD-R, CD-RW and DVD-ROM drives using purchased mechanisms.

CITIZEN WATCH CO., LTD.
2-1-1, Nishi-Shinjuku
Shinjuku-ku, Tokyo 160

1998 total net sales: $2,949,351,100 Net income: $104,488,540

Citizen is steadily expanding its diversification into additional products, from its basic position of strength as Japan's second largest watch manufacturer. Watches are 62% of sales. In addition to printers, displays, and small computers, Citizen introduced 3.5" microfloppies in 1984, offering the first one inch high floppy drive, and began an aggressive sales program in the U.S. and Europe, aimed at the OEM market.

In 1989, Citizen again led the industry in drive packaging, this time with the first introduction of 19 millimeter high 3.5" floppy disk drives, followed in 1990 with drives only 15 millimeters high. A 20.6 megabyte (formatted) floppy drive using metal powder media was announced in late 1989, and since dropped due to weak market reaction. In late 1992 Citizen announced the thinnest 3.5" floppy drive to date, only 11 millimeters in height, and production began in 1993. Cost pressures are forcing Citizen to rethink the wisdom of concentrating on the 11 millimeter form factor, as its components are more expensive. Citizen has been licensed by Iomega to manufacture and sell the Clik! drive, and the firm has started a contract manufacturing program for Iomega.

CYBERDRIVE (See Pan-International)

DELTA ELECTRONICS, INC.
144 Min Chuan East Road, Section 3
Taipei 10464
Taiwan

Founded in 1971, Delta manufactures a variety of electronic items, including power supplies, monitors and other items for computers. The company also assembles CD-ROM and CD-RW drives, using purchased mechanisms. The company has increased its market share in recent years.

ELITE PERIPHERALS (Subsidiary of Elitegroup Computer Systems Co., Ltd.)
88 Chung Shan North Road, Section 6
Taipei
Taiwan

Motherboards and accessories for personal computers are Elitegroup's primary business. Elitegroup showed a family of CD-ROM drives manufactured with Sony mechanisms at the 1994 COMPUTEX show in Taipei and has since produced a moderate number of drives, many of which sold through reseller channels under the Vertos brand name. Elite Peripherals sold the drives under its own name, but stopped production in 1999.

EPO SCIENCE AND TECHNOLOGY, INC.
4F, 310 Chukwang Road
Taipei
Taiwan

EPO was founded in 1998. The firm manufactures CD-ROM drives ranging from 36X to 48X in performance. Sales are primarily through distribution, notably within Taiwan and to Europe, where sales and support are provided by CTX.

FUJITSU, LTD.
1-6-1, Marunouchi
Chiyoda-ku, Tokyo 100

1999 total net sales: $40,022,793,000 Income: ($104,106,870)

Fujitsu is Japan's largest producer of computer systems and also manufactures a wide variety of other electronic equipment. Computer products represent about 69% of Fujitsu's sales.

In 1989, Fujitsu began to ship a computer system with a bundled CD-ROM drive, one of the first companies anywhere to take such a step. In 1992, Fujitsu began shipping a 5.25" optical library and a high performance 5.25" rewritable drive jointly developed with NTT, the first 5.25" optical drive to rotate at 5,400 RPM. Despite its early participation, Fujitsu declined to participate in the 5.25" optical market in a major way.

Fujitsu also scored another "first" with its August, 1992, announcement of a 25.4 millimeter high 3.5" 128 megabyte magneto-optic disk drive. Since that time, Fujitsu has priced its 3.5" products aggressively and has been largely responsible for the growth of the 3.5" MO market since 1995. The firm was among the earliest to introduce a 230 megabyte 3.5" drive, has succeeded in capturing the largest share of the 3.5" market, and has expanded its production capacity for 3.5" drives. Fujitsu is one of the pioneers with the 640 megabyte 3.5" MO drive, and has maintained its pioneer status with announcement of a 1.3 gigabyte model for shipment later in 1999. The 1.3 gigabyte media is provided by Sony.

The firm has also introduced a 3.5" library, which went into production in 1995. The library mechanism is also used by PFU, a computer system and software company partially owned by Fujitsu.

HITACHI, LTD.
6-2, Otemachi 2-chome
Chiyoda-ku, Tokyo 100

1999 total net sales: $60,895,984,000 Net income: ($2,586,213,700)

Hitachi remains Japan's largest manufacturer of electrical and electronic equipment and a major producer of computer systems. It manufactures rigid disk drives and other peripherals as well as processors. About 55% of 1998 revenues were derived from computing and electronic equipment.

Hitachi was one of the earlier entrants in the optical disk drive market, and the CD-ROM and read/write drives are available in the U.S. as well as in Japan. Hitachi' first write-once 12" optical disk drive has a capacity of 1.3 gigabytes, and began shipping in 1984. In addition to drives, Hitachi makes components used in optical drives such as lasers and special chips.

CD-ROM drives began shipping in 1985, and Hitachi initially targeted the high performance drive segment of the market because of its more stable price structure and higher margins. The CD-ROM product line was expanded in 1986 and 1987 to include 5.25" form factor drive packaging and some new features. Later products emphasized performance and cost improvements and half high form factors. Hitachi is also a major producer of components used in CD-ROM drives. Hitachi's OEM sales for CD-ROM drives dipped after 1990, but a revitalization of the OEM oriented CD-ROM product line reestablished Hitachi as a major producer. Hitachi has also taken an aggressive position regarding DVD-

ROM, being among the first to introduce a 2X DVD-ROM drive, and was the first to announce a DVD-RAM drive, providing samples in mid-1997 and commencing volume shipments in 1998.

Hitachi made a 1998 technology announcement of a 3.5" erasable drive developed in its Central Research Laboratory, but the first Hitachi rewritable drive to be announced was a 322 megabyte 5.25" model in March of 1989. The firm began shipping a 5.25" one gigabyte per side magneto-optic drive in late 1993. A 1.3 gigabyte per side drive using light intensity modulation to provide direct overwrite capability (LIM-DOW) began shipments in 1996.

Hitachi has also sold automated library storage units for use with 12" and 5.25" drive designs, marketing its libraries on an OEM and captive basis. Media for Hitachi drives is made by Hitachi Maxell. Hitachi's optical libraries were sold mostly in Japan, but had difficulty capturing an appreciable share of the U.S. market and were discontinued, due to disappointing sales.

HOPAX INDUSTRIES
No. 51, Section 2
Chung Ching South Road
Taipei
Taiwan

Hopax got started in the CD-ROM business as a manufacturer of optical pickups. The firm leveraged this experience with its own double speed drives starting in 1994, and with a quad speed drive in 1995. 32X and faster drives were available in 1998. The company ceased drive production in late 1998.

JVC (VICTOR COMPANY OF JAPAN, LTD.)
1-4 Nihonbashi-Honcho
Chuo-ku, 103 Tokyo

1998 total net sales: $7,566,515,000 Net income: ($38,827,000)

JVC, as it is commonly known, is a major manufacturer of consumer audio equipment, including CD players. Matsushita Electric Industrial (MEI) holds a 52.4% share in the company. Since 1985, JVC has experimented with several computer peripheral programs. The firm introduced CD-ROM drives and went into low volume production in the last half of 1987, but has since withdrawn from the CD-ROM market except for some contract manufacturing. A CD-R drive went into sample production in late 1991, along with additional mastering subsystems. Full production began in the second quarter of 1992. CD-RW drives began production in late 1997. JVC also manufactures CD-ROM optical libraries, equipping many of them with CD-R and CD-RW drives.

KENWOOD
1-14-6, Dogenzaka
Shibuya-ku, 150 Tokyo

1998 total net sales: $2,577,828,000 Net income: $13,873,000

Kenwood is one of the largest manufacturers of audio equipment and also manufactures communications equipment. In an initiative to broaden into other electronics technologies, the company established Kenwood Technologies in 1997 to create and market products for computer systems.

Kenwood Technologies, in conjunction with development partner Zen Research (which provides pickup, ASIC and other technology), designed and manufactures a CD-ROM drive capable of reading and processing multiple tracks of data at a time. The drive provides a data transfer rate well in excess of conventional CAV drive technology while maintaining CLV rotation rates. Production, which is scheduled to begin in the summer of 1999, is in the Philippines. Kenwood expects to sell the drives through distribution and to system OEMs. An eventual extension of the multitrack read approach to DVD drives is anticipated.

KONICA CORPORATION
1-26-2 Nishi-Shinjuku
Shinjuku-ku, Tokyo

Konica is a well known camera and photographic materials manufacturer, but about 31% of sales are non-photographic business and computer equipment. The firm made floppy disk drives for a few years, but then transferred its storage interests to 3.5" MO disk drives, which it manufactures on a contract basis for other firms. A 640 megabyte drive (which spins at 4500 RPM) is currently in production, and a 1.3 gigabyte drive is planned for 1999. Production is at Kofu and Yamanishi.

KYUSHU MATSUSHITA ELECTRIC CO., LTD.
Subsidiary of Matsushita Electric Industrial Co.
4-1-62 Minoshima, Hakata-ku
Fukuoka 812

1998 total net sales: $3,201,387,000 Net income: $27,655,000

KME, which originally produced transformers and electric pumps, is one of the Matsushita group's largest manufacturing companies, producing a range of electronic components (including magnetic and optical heads), cordless phones, and office equipment. MEI has 51.1% ownership. About 73% of revenues come from information, office and video equipment. The company manufactures CD-ROM pickup and positioning assemblies and has begun manufacturing thin drives for other companies. The CD-ROM drives are manufactured by KME's Kikusui division. KME has become a significant supplier of thin CD-ROM mechanisms for notebook computers, offering some as thin as 9.5 millimeters, to match the height of thin rigid drives used in portable computers. Thin CD-RW drives are anticipated in the future.

LEOPTICS INC.
100-1 Ming Chuang Road
Hsin Tien City
Taipei
Taiwan

Founded in July of 1997, Leoptics is a member of First International Computer, Inc., Group, a major Taiwanese system manufacturer. The firm builds its drives around purchased mechanisms, adding the electronics and packaging to create a complete drive. Leoptics currently supplies CD-ROM and CD-RW drives.

LG ELECTRONICS, INC.
20 Yoido-dong
Youngdungpo-gu
Seoul 150
South Korea

1998 total net sales: $9,718,100,000 (FY ending 12/31/97)   Net income: $96,339,900

All of the companies in the Lucky-GoldStar group adopted the "LG" name in early 1995. LG Electronics was founded in 1959, and is one of Korea's major producers of consumer electronics. The company's current strategy involves expansion of its industrial electronics divisions, including computers and peripherals. The company currently offers CD-ROM drives and DVD-ROM drives, and has become one of the world's largest producers of CD-ROM drives. Riding a major surge in orders, LG Electronics became the leading manufacturer in CD-ROM shipments in 1998. The company also is producing increasing quantities of DVD-ROM and CD-RW drives.

LITE-ON TECHNOLOGY CORPORATION
16 Nanking East Road, Section 4
Taipei
Taiwan

1998 total net sales: $1,885,000,000
(FY ending 12/31/97)

Established in 1989, Lite-On became a major producer of monitors. In late 1995, the firm established an optoelectronics business unit and constructed a factory to produce CD-ROM drives. A major ramp up occurred in late 1996 and 1997 as new production capacity was added in Taiwan and offshore locations. Lite-On is now the CD-ROM shipment leader among companies in Taiwan. The company delayed its DVD plans to component shortages, but expects to produce DVD-ROM drives starting in late 1999.

MATSUSHITA COMMUNICATION INDUSTRIAL CO., LTD.
Subsidiary of Matsushita Electric Industrial Co., Ltd.
4-3-1 Tsunashima-Higashi
Kohoku-ku, Yokohama 223

1998 total net sales: $6,593,648,800 Net income: $242,442,740

Matsushita Communication Industrial is a member of the Matsushita Electric Industrial group, a worldwide giant in appliances and electronics. During the early growth of the floppy drive industry, MCI manufactured most of the Shugart Associates floppy drive line under license for the Japanese OEM market. MCI later added floppy drives of its own design, including half high 5.25" and 3.5" microfloppy drives. The firm made half high 5.25" drives on a contract manufacturing basis for Shugart and in 1985 acquired marketing rights in the United States, which has resulted in significant sales by the firm's U.S. Panasonic subsidiary. MCI established a joint venture in the Philippines with Precision Electronics Corporation, to manufacture floppy disk drives and other computer components, and all flexible disk drive production is now located in the Philippines.

MCI introduced a .7 megabyte 2" floppy drive that was adopted by Zenith in 1989 for use in a notebook computer but was otherwise shunned by the computer industry. The company made several attempts to pioneer various internally developed high capacity floppy drive configurations, most with only modest improvement over standard 5.25" and 3.5" floppy drive capacities. In 1996, MCI took a Zip license from Iomega, and started production of the Zip 100 megabyte drive in 1998.

MATSUSHITA ELECTRIC INDUSTRIAL CO., LTD.
1006, Kadoma City
Osaka, 571

1999 total net sales: $58,321,519,000 Net income: $103,366,410

MEI's Panasonic, National, Technics, and Quasar brands are among the most widely known in the world for appliances, consumer electronics, and communications equipment. Subsidiary Matsushita-Kotobuki Electronics produces CD-ROM drives for sale by MEI. High volume production commenced in 1992, and MKE became 1994's largest producer of CD-ROM drives and mechanisms. Although a bit late in starting production of 4X drives, 1995 production by MKE increased rapidly and Matsushita remained the largest producer of CD-ROM drives until 1997. It is still among the largest non-captive producers.

Building upon its experience with CD-ROM and phase change technology, and inspired by its prominent position in the entertainment industry, MEI has been among the more visible sponsors of DVD-ROM and DVD-RAM. Its DVD-RAM drives entered production in late 1998.

In April, 1987, IBM announced a 200 megabyte write-once disk drive whose mechanism was produced for IBM by Matsushita Electric's Disk Division. The product wasn't a success, although MEI offered similar products under its own brand. The MEI branded product was similarly unsuccessful.

In 1989, the Disk Division of MEI acquired the responsibility for manufacturing and marketing of the Matsushita Communication Industrial optical disk drive product line, adding rewritable drives and optical libraries to the MEI product line. Production of write-once drives has been discontinued.

In 1990, Matsushita announced the first commercially available rewritable phase change drive and media. The 5.25" drive also accepts write-once media, permitting it to operate as a multifunction drive as well. Because no overwrite pass is required, write throughput exceeds that of magneto-optic rewritable drives. However, its unique format and technology have inhibited broad industry acceptance. Moderate success was achieved with the PD drive, a 12 centimeter drive capable of reading CD-ROM disks and writing/reading phase change media, although the phase change media can be read only on PD drives. The PD drive technology has been licensed to NEC and TEAC.

MATSUSHITA-KOTOBUKI ELECTRONICS INDUSTRIES, LTD.
8-1, Furujin-machi
Takamatsu-shi 760-0025

1998 total net sales:$5,987,498,000 (FY ending 3/31/98) Net income: $165,954,000

Matsushita Electric Industrial owns 57.6% of MKE, which was established in 1948. MKE is a major producer of VCRs and other consumer electronic items, some of which are sold by the Matsushita companies and some by other firms. Disk storage products include rigid disk drives made for Quantum, LS-120 high capacity floppy drives, and CD-ROM drives. MKE has manufactured the LS-120 drive from the beginning of the program, with sales through Matsushita companies, Imation and O.R. Technology. Production started in late 1996. CD-ROM drive production, which commenced in 1992, has become quite large, making MKE the leading CD-ROM manufacturer for several years. Much of MKE's CD-ROM output is marketed through Matsushita companies.

MITSUBISHI ELECTRIC CORPORATION
2-2-3 Marunouchi
Chiyoda-ku, Tokyo 100

1999 total net sales: $28,931,200,000 Net income: ($33,969,460)

Mitsubishi is most noted for heavy machinery production, but is also active in defense electronics and consumer electronics. Data and communications systems represent about 45% of revenues.

In the past, Mitsubishi has manufactured 5.25" MO drives, write-once drives (sold to IBM) and optical libraries, but left the optical storage peripherals business in 1993. In 1996, the firm announced a DVD-ROM drive and mechanism, with a production start in 1996. However, in 1997, the DVD-ROM product was dropped.

A family of half high 5.25" floppy drives was introduced in 1982, and Mitsubishi started shipping 3.5" microfloppy drives in 1983. Mitsubishi became a major supplier of flexible disk drives to IBM, following the IBM introduction of PS/2 in 1987, and in 1991 the firm introduced a 2.88 megabyte 3.5" drive which remained in production through 1997, with IBM as the major customer. In 1996, Mitsubishi obtained a license to manufacture LS-120 high capacity floppy drives, starting production that year. After several years of flexible disk drive production at Mitsubishi's Koriyama Works, Melco Manufacturing (Thailand), a joint venture for the manufacture of floppy drives was established with Kang Yong Electric Manufacturing Co. The joint venture is largely owned by Mitsubishi.

MITSUMI ELECTRIC CO., LTD.
8-8-2 Kokuryo-cho
Chofu-shi, Tokyo

1998 total net sales: $2,012,908,300 Net income: $77,572,519

Mitsumi, founded in 1949, is primarily a manufacturer of electronic components, but 46% of revenues are derived from computer and telecommunications equipment. Floppy disk drives represent about 15% of sales. The firm introduced CD-ROM drives in 1988, with most of the drives being sold as attachments to personal computers. Later models have been designed for use with games. Front tray loading drives not requiring a caddy were introduced in 1993. Mitsumi is making a major effort to market CD-ROM drives to firms selling multimedia equipment, and after a rough start seems to have found the formula, showing excellent growth in CD-ROM drive shipments until 1998. In 1995, the firm made very large quantities of 4X CD-ROM drives, becoming the second-largest producer of CD-ROM drives. Mitsumi and Philips jointly announced in mid-1998 that they were working together on advanced CD-RW and DVD-ROM drive development, and Mitsumi has been identified by TeraStor as a manufacturing partner for its near field recording MO drives.

Mitsumi established a joint venture facility with Commodore, named Newtronics, to produce 5.25" and 3.5" floppy drives, and acquired complete ownership of Newtronics in 1986. During the last few years, Mitsumi has established an industry leadership position in floppy drive sales, the result of low cost manufacturing operations and the company's aggressive pricing policy. Mitsumi has established a manufacturing facility in Malaysia for floppy disk drives and began manufacturing at Cebu Mitsumi in the Philippines in early 1992. The company announced a 128 megabyte 3.5" floppy drive based on an Antek Peripherals design in November, 1995. However, production was delayed pending resolution of a patent licensing dispute with Swan Instruments, which was eventually resolved. After extensive delays, Mitsumi dropped the project, probably in favor of eventually taking a license with the most successful high capacity floppy drive program.

NAKAMICHI CORPORATION
1-153, Suzuki-cho
Kodaira City, Tokyo 187

1998 total net sales: $197,664,120 Net income: $7,145,038
(FY ending 12/28/98)

Best known for its top of the line audio equipment, Nakamichi has had an optical disk drive development program for several years, as well as laboratory equipment for optical disk drive development. In 1994, Nakamichi began marketing a seven disk tabletop CD-ROM library derived from an audio library design. The firm has aggressively priced the library and has captured significant market share, including some OEM accounts. Half height four disk CD-ROM autochangers were introduced in 1995 and became the firm's major effort in the optical disk drive market. A five disk, 16X model was introduced in 1997. While the minichangers did well initially, inability to keep up with OEM performance and price demands led to major shipment declines, resulting in restructuring of the firm in 1998.

NEC CORPORATION
5-33-1, Shiba
Minato-ku, Tokyo 108

1999 total net sales: $36,331,389,000 Net income: ($1,205,702,200)

NEC has defined its product area as communications and computers, with computer products accounting for about 42% of revenues. The firm has the largest share of the Japanese personal computer market. NEC makes a variety of data storage products, including floppy, rigid and optical disk drives. The firm's first optical drive, introduced in 1983, was a 1 gigabyte, 12" unit used primarily for NEC captive document storage systems, but also sold on an OEM basis. A 2.5 gigabyte drive was introduced in 1990. A 5.25" MO rewritable drive began production in mid-1989, and a 650 megabyte per side version was introduced in mid-1993. A direct overwrite version with 1.3 gigabytes per side capacity began shipping in early 1996.

CD-ROM drives have been produced since 1992. As a result of increased demand beginning in 1992, NEC significantly expanded its production capacity for CD-ROM drives, becoming one of the market's major suppliers through its NEC Home Electronics business unit. NEC also entered the CD-ROM autochanger market, although this activity has since been discontinued. NEC has licensed Matsushita's PD drive and phase change technology. The PD production ramp was scheduled for the spring of 1996, but technical difficulties forced a rescheduling to late 1996.

Starting in 1978 the company manufactured two sided 8" floppy disk drives, and was one of the earliest firms to offer half high 8" floppy drives, with shipments starting in late 1981, and not phased out until 1996. 3.5" microfloppy drives and half high 5.25" drives were introduced in 1984. While NEC's production of 3.5" low capacity floppy drives was originally destined primarily for captive applications, the company in recent years has become a major participant in noncaptive markets.

NEC was an early participant in the high capacity floppy drive market with the 1988 introduction of a 3.5" 9.4 megabyte drive for sale with its microcomputer systems. A 10 megabyte version with downward compatibility to .7 and 1.44 megabyte drives was introduced in 1990. NEC was very active on the JEIDA committee working to standardize high capacity 3.5" floppy disk drives, and announced a 21.4 megabyte drive. NEC high capacity floppy drive production for its own designs was limited, and all have been dropped. In 1997, NEC announced that it had taken an Iomega license to manufacture the Zip 100 megabyte drives. Also in 1997, the NEC division responsible for notebook computers announced that it would use the new 12.7 millimeter high LS-120 drives in some of its notebook computer models.

NIKON CORPORATION
3-2-3, Marunouchi
Chiyoda-ku, Tokyo 100

1998 total net sales: $3,073,039,000 Net income: $68,687,000

Nikon, a member of the Mitsubishi group, is best known for its popular line of cameras and other optical equipment. The firm is also a significant supplier of semiconductor production equipment, medical optical instruments, microscopes and telescopes, and other optical instruments. As a way of expanding its scope of business, in 1992, Nikon introduced the first 12" magneto-optic drive sold as a computer peripheral device, a 2 gigabytes per side erasable optical drive. Nikon's drive was initially sold only in Japan, but after a round of redesign and cost reduction, was also marketed in the U.S. Shipments were weak, and the drive was discontinued in 1997. A 5.25" LIM-DOW MO drive, developed in conjunction with Hitachi, was introduced in 1996. Nikon never developed significant sales of optical drives, and elected to withdraw from the market in 1999. The company continues to supply optical media.

O.R. TECHNOLOGY, INC.
Subsidiary of O.R. Computer System Pte. Ltd.
1730 Conestoga Street
Boulder, CO 80301

O.R. Technology, Inc., was formed in November, 1995, as a combination of Insite Peripherals and Optics Research. Insite's announcement of a 20 megabyte 3.5" microfloppy, an optical head positioning scheme with magnetic recording, aroused widespread interest in the disk drive industry at the beginning of the 1990's. Trademarked as the "floptical", the drive used an LED on the head assembly to follow optically reflective servo tracks on the surface of 3.5" barium ferrite media. A one inch high version, downward compatible with standard 3.5" .7 and 1.44 megabyte drives in both read and write modes, became available in late 1991, the result of Insite's contract manufacturing arrangement with Matsushita-Kotobuki Electronics. Insite attempted to achieve mainstream status through licensing of established drive and media manufacturers, with Iomega as the first announced licensee. 3M and Hitachi Maxell were granted licenses as media producers, and made equity investments in Insite.

Despite establishment of reliable drive and media manufacturing sources, the Insite drive's relatively high price discouraged personal computer manufacturers from adding optical drives as standard products. The limited floptical market was confined to storage subsystems builders active in the add-on market and to OEM sales for specialized applications. In order to develop a higher capacity drive with a potentially larger market, several of the companies participating in the floptical program established Optics Research in Boulder, Colorado, to undertake development of a 120 megabyte backward compatible version of the floptical drive. Before completion of the project, Iomega dropped out of the program, in order to develop its own high capacity floppy drive, without backward compatibility, which was introduced in 1995 as the "Zip" 100 megabyte drive. The Optics Research program resulted in the 1995 introduction of the LS-120, with drives to be manufactured by Matsushita-Kotobuki Electronics and media to be supplied by 3M (now Imation).

In the meantime, Insite's development activities and other operations were funded by several rounds of venture capital investments, which were mostly exhausted by the second half of 1993. In late 1993, Insite was sold to O.R. Computer, a subsidiary of Ocean Radio Group, based in Singapore. Ocean Radio has been active for 50 years as a trading company in consumer electronics, components, computers and peripherals. With the new owner's financial backing, the manufacturing arrangement with MKE was continued and sales of the 20 megabyte floptical continued until 1996. With the start of MKE's production of the 120 megabyte LS-120 in the second half of 1996, O.R. Technology has sold the drive through distribution and system integrator channels, in addition to direct sales by Matsushita to system manufacturers.

OLYMPUS OPTICAL CO., LTD.
22-2, Nishi-Shinjuku 1-chome
Shinjuku-ku, Tokyo

1998 total net sales: $3,013,889,000 Net income: $76,870,000

Founded in 1919, Olympus Optical Company is known primarily for cameras and optical instruments. In recent years, the company has broadened its activities to include electronics and some specialty products, including optical heads for disk drives. Development of optical disk drive technology began in 1981 when Olympus and Fujitsu began a joint project that resulted in one of the first commercial write-once optical disk drives. The firm's optical electronic products include optical heads, an optical card reader compatible with the Drexler Lasercard and a 5.25" erasable optical disk drive announced in November, 1987. The disk drive, which had a capacity of 326 megabytes per side, was provided in sample quantities as of mid-1988, and Olympus mechanisms were adopted by several manufacturers as the basis of their own rewritable drives.

Olympus began marketing under its own name in 1992 when it introduced a 3.5" 128 megabyte drive. This was followed by a 230 megabyte version in early 1994. At that time the firm also announced 5.25" full height and half height MO drives. The company has expanded its marketing channels in the United States for the drives, and in early 1994 adopted the brand name "Deltis" for its externally packaged drive subsystems and related products, including libraries and CD-R drives. In 1996, the firm introduced a reduced cost and aggressively priced ($299) 3.5" 1 inch high MO drive and a 1.3 gigabyte per side 5.25" drive, becoming a major supplier of 3.5" drives as a result. The product line currently includes 640 megabyte 3.5" drives.

PAN-INTERNATIONAL CORPORATION (Cyberdrive)
504-2 Section 4, Chung Hua Road
Hsin-Chu
Taiwan

Formed in 1996, Cyberdrive began assembling CD-ROM drives using mechanisms procured from Japanese firms and electronics manufactured in Taiwan. Most sales are in the U.S., but the firm also supplies some drives on an OEM basis to local companies. In July, 1997, Cyberdrive was acquired by Pan International Corp., a manufacturer of cables, connectors and other equipment. Pan-International rapidly built up CD-ROM production capabilities, achieving a place as one of Taiwan's larger CD-ROM drive producers. 24X and 32X drives are the firm's primary CD-ROM products. The firm has retained the Cyberdrive brand.

PIONEER ELECTRONIC CORPORATION
4-1, Meguro 1-chome
Meguro-ku, Tokyo 153

1999 total net sales: $4,342,419,800 Net income: $8,847,328

Pioneer, founded in 1947, is a major manufacturer of consumer electronic equipment. 89% of Pioneer's revenues come from sales of audio, video and automotive electronic equipment. The firm is especially strong in the laserdisc and automotive audio CD markets.

Pioneer and Ricoh had a joint development program on an 8" 750 megabyte optical write-once disk drive, with Ricoh being Pioneer's most significant customer for the product. First shipments began in late 1985, and Pioneer has established a separate division to make and sell the product. Pioneer also developed a 5.25" write-once drive, with first shipments in mid-1988. The media used in these drives is a cyanine dye-based type that appears to offer superior resistance to corrosion. Pioneer's media was the first commercial version of dye-based media to be brought to market. In 1990, Pioneer introduced a multifunction, sampled servo drive using dye or MO media interchangeably.

In 1989, Pioneer introduced a CD-ROM drive integral to an automatic library mechanism. The library contains up to six disks and is derived from a design developed for use with audio CD players and disks. A version with quadruple rotation and data transfer rate was first shipped in 1992. Subsequent models increased disk capacity, and libraries with capacities up to 500 disks have been shown. A network attached version was announced in mid-1999. In the second half of 1996, Pioneer began a marketing effort to sell Pioneer brand CD-ROM and DVD products in the U.S., including a 10X CD-ROM drive with dual CAV and CLV modes, the first CD-ROM drive of that type. Pioneer was also the first company to market DVD-R drives, and is a primary sponsor of the DVD-RW rewritable recording format.

PLEXTOR (SHINANO KENSHI)
1078 Kami-maruko
Maruko-machi, Chiisagata-gun
Nagano-ken

Shinano Kenshi was founded in 1918 as a silk spinning company. The company has produced CD players, printers, and floppy disk drives under contract for other companies. In 1989, the firm began selling a CD-I encoding system. CD-ROM drives bearing the firm's own label first shipped in 1990, but subsequently have appeared under the Texel brand. The half high drives are available in internal and external configurations. In 1992, Texel began shipping a double speed RPM drive in internal and external configurations, following up in 1993 with a high performance version. The firm achieved a moderate degree of success selling through reseller channels in the United States. In 1994, the firm changed its identity and now markets CD-ROM drives under the Plextor name. Plextor was one of the first companies to announce and produce a 6X CD-ROM drive, which began its production run in mid-1995. Faster drives have been announced subsequently. Plextor is one of the few companies to retain the caddy as a standard feature, which has helped the company gain entry into the CD-ROM jukebox market as a drive supplier.

Plextor also produces host and network attached CD-ROM towers, and is the U.S. marketing channel for Nippon Columbia's line of CD-ROM libraries.

RICOH CO., LTD.
15-1, Minami-Aoyama 1-chome
Minato-ku, Tokyo 107

1999 total net sales: $10,885,488,000 Net income: $234,007,630

Copiers, photographic equipment and sensitized papers provide most of Ricoh's revenues, but the firm also produces a growing line of data processing equipment, which accounts for 21% of current revenues. Ricoh and Pioneer developed an 8" write-once optical drive which Ricoh used in a document storage system. However, Ricoh concentrated upon developing optical disk drives in the 5.25" form factor, rather than expending further effort on an 8" product.

After several years of optical disk drive manufacturing activities involving write-once and MO drives, Ricoh has concentrated in recent years on CD-R and CD-RW drives. Ricoh began manufacturing CD-R drives in 1993, and is among the more aggressive marketers for this type of drive. A cost reduced double speed drive went into production in early 1995, followed by a 4X read, 2X write model in 1996. Ricoh began the manufacture of CD-RW drives in 1997.

SAMSUNG ELECTRO-MECHANICS CO., LTD.
314, Maetan 3 Dong, Paldai-Ku, Suwon
Kyungki-Do
South Korea

1998 total net sales: $2,612,219,000 (FY ending 12/98) Net income: $48,327,520

Part of the Samsung electronics business group, Samsung Electro-Mechanics is a diversified electronics component manufacturer with almost 10,000 employees. In 1995, the firm began a major expansion into automotive parts, and in the same year the Samsung Electronics floppy disk drive business was transferred to Samsung Electro-Mechanics. Samsung Electronics got started in floppy drive production in 1983 when Shugart Associates granted a license to manufacture and market the Shugart floppy drives in South Korea.

Samsung Electro-Mechanics produces most components used in its floppy drives internally, with a concentration on 3.5" low capacity floppy drives in both one inch high and half inch high models. The firm has announced a program to introduce a high capacity floppy drive by the end of 1999.

SAMSUNG ELECTRONICS
7 Soonwha-Dong
Seoul
South Korea

1997 total net sales: $19,420,866,051 (FY ending 12/31/97) Net income: $129,895,781

Founded in 1969, Samsung Electronics is Korea's largest manufacturer of electronic products, which range from semiconductors, to telecommunications equipment, disk drives and computers. About one fifth of the firm's revenues are derived from information systems and related products. Disk drive products include rigid and optical disk drives. In 1992, a 5.25" MO drive was announced, but the firm decided not to place it into production. A double speed CD-ROM drive was announced in late 1993, and was joined by a 4X drive in mid-1995. Faster drives have subsequently been added to the product line, which now extends to 32X, as well as DVD-ROM and CD-RW drives.

SANYO ELECTRIC CO., LTD.
2-18 Keihan-Hondori
Moriguchi, Osaka 570

1999 total net sales: $13,879,030,000 Net income: ($197,580,150)

Sanyo is a major supplier of facsimile equipment, consumer electronics, appliances, batteries and components such as solar cells, and is one of Japan's more active offshore manufacturers, especially in China. About 32% of sales are computing and business equipment. Sanyo is actively involved in CD equipment, component and media production and introduced a CD-ROM drive in 1987. Shipments began in 1988. Half high drives began shipping in 1989, and a portable version was introduced in 1991. Sanyo and its subsidiaries currently produce several models of CD-ROM drives. Sanyo is also manufacturing CD-R and CD-RW drives, the latest an 8X write, 20X read model introduced in 1998.

SEGA ENTERPRISES, LTD.
1-2-12 Haneda
Ohta-ku, Tokyo 144

1998 total net sales: $2,738,274,000 Net income: $294,261,000

Sega, founded in 1960, is one of the world's major producers of electronic games and arcade equipment. About three fourths of its sales are derived from consumer equipment. The CD-ROM drives included with the games are made on a contract basis for Sega by several firms.

S.F.R.
7-5-17 Nakazato
Tendo-shi, Yamagata 994

S.F.R., founded in October, 1988, originally was called Digital Systems, Inc., and later adopted the name of its major distributor, Japan Peripherals Network (JPN). In 1991, the firm adopted Safronic Corporation as its name, with JPN remaining a separate organization distributing peripherals, including floppy disk drives made by Safronic, and transitioned to the S.F.R. name in 1995. The company has used contract manufacturing sources for half high 5.25" drives and 1.44 megabyte 3.5" drives, but eventually found that prices for low capacity floppy drives had fallen too low to justify remaining in the business.

SONY CORPORATION
6-7-35, Kitashinagawa
Shinagawa-ku, Tokyo 141

1999 total net sales: $51,867,320,000 Net income: $1,366,442,700

Sony is a leader in consumer electronics and has also earned a position as a leading supplier of 3.5" floppy disk drives. TV, VCR, and audio products make up about 55% of revenues. Sony also holds the largest share of the 5.25" magneto-optic disk drive market. The company is vertically integrated and supplies its own media, and is currently the largest producer of magneto-optic media. Sony has consistently ranked among the largest CD-ROM drive producers for the past several years.

Because of its strong position in the audio CD player market, Sony is very competitive in the CD-ROM marketplace with products aimed at the personal computer and small systems market. Sony, together with Philips, has been a moving force in establishing standards for CD and CD-ROM devices and in the CD-I multimedia standards effort. The firm is also one of the leading proponents of the DVD+RW recording format, and anticipates drive production beginning in late 1999.

Sony fields a product line of CD-ROM, CD-R, CD-RW, write-once and multifunction optical drives. Rewritable 3.5" MO drives have been deemphasized, although some development on higher capacity models continues. The 5.25" rewritable and multifunction drive product line remains strong, partially as the result of Sony's absorption of discontinued product lines of other companies.

To support its 12" write-once drives, Sony offered automated library units, but the 12" line was discontinued in early 1997. In 1994, Sony introduced its first 5.25" library, a 20 disk model, followed by a 60 disk library in 1995. Sony manufactures its 5.25" libraries in the United States but has also filled in its line of optical libraries with models purchased from other suppliers. An aggressively priced CD-ROM library was announced in 1997.

In mid-1990, Sony introduced the Data Discman, a portable CD-ROM system using the first 8 centimeter CD-ROM drive to go into production. The product was introduced in the U.S. in late 1991. The Sony PlayStation, a game system introduced in 1995, has done well, although competition from CD-ROM games for personal computers have restrained sales.

In 1987, Sony announced and shipped its first few erasable 5.25" optical drives, using magneto-optical technology. Production units were shipped in late 1988, and since 1989, Sony has been the largest supplier of 5.25" rewritable optical disk drives. Sony's 5.25" program languished for a few years, but has benefited from decisions by IBM and HP to cease drive manufacturing, leaving Sony as the leading manufacturer in shipment volume.

Sony introduced a 3.5" 128 megabyte rewritable MO drive in mid-1991. The drive had a specified average seek time of 40 milliseconds and rotated at 3,000 RPM, among the faster optical drives. Sony surprised the industry when it failed to announce a 230 megabyte 3.5" drive in early 1994, and subsequently exited the 3.5" drive segment.

Sony announced the MiniDisc, a 2.5" magneto-optic drive intended for use in a portable audio recorder, and currently in production as an audio device, in 1991. In mid-1993, Sony announced a proposed standard for the MD-DATA, a 140 megabyte CLV 2.5" magneto-optic drive with 150 kilobyte per second data transfer rate. A separate erase pass is not required. Modest shipments began in 1994. Sony is also looking for opportunities to apply the MD-DATA technology to other form factors.

In 1981 Sony introduced the first drive using a 3.5" flexible diskette, which became the industry's floppy drive standard after several years of struggling with other formats for market dominance. After several generations of floppy drives, Sony's product line evolved into low-cost models in the standard 25.4 and 12.7 millimeter package heights, and the company remains one of the industry production leaders. Sony pioneered the submicrofloppy field with a very high bandwidth .7 megabyte 2" floppy disk drive based upon a Mavica video camera storage device, but the data version of the 2" drive did not find a following in the computer industry. In October, 1997, Sony and Fuji Photo Film announced the HiFD, a 3.5" 200 megabyte backward compatible floppy drive, with delivery set for the second quarter of 1998. TEAC and Alps Electric were later added as licensees. Sony missed the promised delivery date, and eventually shipped a small quantity of HiFD drives in late 1998, with disastrous results. Most of the drives had reliability problems, and the product was quickly, and quietly, removed from the market. Sony now plans to reintroduce the HiFD in the Autumn of 1999.

TATUNG COMPANY
22 Chungshan North Road, Section 3
Taipei 10451
Taiwan

Tatung was founded in 1918 and has grown to become a major supplier of industrial and electronic equipment. The company assembles CD-ROM drives using purchased mechanisms. Most drives are used with Tatung's line of personal computers.

TEAC CORPORATION
3-7-3 Naka-cho
Mushashino, Tokyo 180

1998 total net sales: $1,142,956,000 Net income: $31,932,000

TEAC is best known for its leadership position in the flexible disk drive industry, but the firm also manufactures optical disk drives. About 75% of revenues come from sales of computer peripheral devices. TEAC has produced CD-ROM drives for several years, starting with 4X drives introduced in 1994. The firm is currently shipping 32X drives, and plans to ship 40X drives in the fall of 1999. The TEAC line includes slim drives up to 24X for use in notebook computers. 5X DVD-ROM drives are also being shipped in slim configuration. TEAC manufactures CD-R and, as of the fall of 1999, CD-RW drives. The company is also a PD drive licensee and producer.

Shipments of 5.25" floppy drives for the market started in 1978, and in 1985 TEAC announced its line of 3.5" drives, including a 1.44 megabyte model and subsequently added one inch high models. Rapid growth made TEAC (which claims over 150 million floppy drive shipments to date) the leader in worldwide noncaptive floppy drive revenues during the early 1990's, and the company did not lose the industry's shipment leadership until 1996.

The firm joined Toshiba in 1987 in announcing 2.88 megabyte 3.5" floppy drives using barium ferrite media, but without significant results. 19 millimeter high 3.5" drives were introduced in 1989, and in 1991 TEAC introduced the industry's first 12.7 millimeter high 3.5" floppy disk drive, moving to the front in the race to downsize microfloppy drives. TEAC has made manufacturing and licensing arrangements with a number of firms in Japan, Korea, and other countries, including a deal with Sony to enter the market for HiFD 200 megabyte 3.5" floppy drives. Much of TEAC's current production has been moved to Malaysia. The company has also established a drive component manufacturing operation in Singapore.

TOSHIBA CORPORATION
1-1-1, Shibaura
Minato-ku, Tokyo 105

1999 total net sales: $40,464,900,000 Net income: ($106,076,000)

Toshiba is a major factor in consumer electric and electronic products, and also has a leading position in the office computer market in Japan. About 68% of revenues are related to data communications or computer products. Toshiba produces optical and rigid disk drives, and was one of the first firms to market a 12" write-once drive, which began shipments in 1988. Toshiba shipped production 5.25" write-once optical disk drives in early 1989 (although it began shipping samples in 1986). However, 5.25" drive shipments never reached appreciable levels and the company withdrew from the write-once market in 1992. Toshiba showed a 3.5" MO drive at the 1991 Tokyo Business show, but sold it only in for a short period.

CD-ROM shipments began in 1986 and fared much better. Toshiba became the leading producer of CD-ROM drives in 1997, helped by a large production volume of slim drives for its own notebook computers. Toshiba's later CD-ROM models have unusually fast seek times for CD-ROM drives, helping Toshiba capture a significant market share. The high performance drives are particularly favored by system integrators building file servers incorporating CD-ROM, and as early as 1990, Toshiba CD-ROM drives appeared in the product lines of major system manufacturers, including IBM.

An 8 centimeter CD-ROM drive was announced in 1992, but has since been withdrawn. Slim drives used in notebook computers are becoming increasingly prominent in Toshiba's own notebook computers, and Toshiba holds a major share of the slim profile CD-ROM market. DVD drives are also a major Toshiba initiative, with Toshiba among the early introducers and shippers of DVD and DVD-ROM drives. DVD-RAM drive shipments began in 1998.

Toshiba was an early manufacturer of 8", 5.25" and 3.5" floppy drives. High capacity barium ferrite media was developed by Toshiba for 2.88 megabyte 3.5" floppies, with production of drives and media starting in 1988, and several other firms licensed the drive and media. In the 1990's, Toshiba deemphasized floppy drive manufacturing, and relied on contract manufacturing arrangements for its floppy drive product line, and eventually discontinued the program.

ULTIMA ELECTRONICS CORP. (Artec)
18, Alley 1, Lane 768
Section 4, Pa Te Road
Taipei
Taiwan

Ultima was founded in 1983 as a manufacturer of keyboards, and has since branched out into peripheral equipment, perhaps best known for its scanners. 24X CD-ROM drives went into production in 1997, followed by 32X and 36X in 1998. CD-RW drive production is planned for late 1999.

UNITRON INC.
542-3 Chung Cheng Road
Hsin Tien 23138
Taipei
Taiwan

Unitron had assembled CD-ROM drives using purchased mechanisms since 1995. Most of Unitron's drives were sold in Japan. Production ceased in late 1998.

USDRIVES TECHNOLOGY CORP.
850 Auburn Court
Fremont, CA 94538

Established in 1997 to provide a U.S. source for CD-ROM drives, the firm assembled mechanisms from Japan and boards produced by Cyberdrive, a sister company in Taiwan, into complete CD-ROM drives, which were then sold through distribution and to OEMs. After Pan International acquired Cyberdrive, production was done entirely by Pan International.

WEARNES PERIPHERALS INTERNATIONAL (PTE) LTD.
Joint venture of WBL Corporation, Winbond Electronics and Walsin Lihwa
801, Lorong 7, #07-00
Toa Payoh
Singapore 1231

Wearnes Technology, a subsidiary of WBL Corporation, (formerly Wearnes Brothers) and itself a multinational corporation with development and manufacturing operations in Asia, Europe and in the U.S., manufactures computers, tape drives, displays, many kinds of components and, beginning in 1993, CD-ROM drives. The company selected Philips mechanisms as the base for its products. The firm subsequently produced CD-R and CD-RW drives.

Wearnes Technology also acquired a 25% share of Behavior Tech Computer Corporation, a Taiwan company that has also produced CD-ROM drives. Wearnes Peripherals International (WPI) was established in early 1995 as a joint venture between WBL, Winbond Electronics (a Taiwan semiconductor producer) and Walsin Lihwa (a Taiwan conglomerate), and all of Wearnes Technology CD-ROM disk drive activities were transferred to WPI. WPI has facilities in Singapore, Malaysia and China, producing CD-ROM drives with IDE/ATAPI interfaces.

YAMAHA CORPORATION
10-1 Nakazawa-machi
Hamamatsu, Shizuoka

1998 total net sales: $5,028,819,000 Net income: $111,272,000

Yamaha is the world's largest manufacturer of musical instruments, which account for 55% of the firm's sales. The firm is also a major supplier of thin film heads for rigid disk drives. In 1998, Yamaha and TeraStor began joint development of heads for TeraStor's near field recording MO drive.

Yamaha was the first to develop CD-R systems capable of recording on write-once media and produced the first commercial write-once CD format drive. The firm followed up with a greatly cost reduced 4X recorder that went into production in 1994 and a 2X write/4X read model introduced in 1996. Faster models, including CD-RW drives, continue to be regularly introduced, and are frequently selected by manufacturers of CD format duplicating systems. Manufacturing in Southeast Asia to reduce production costs is expected to begin in late 1999.

Y-E DATA, INC.
182 Shinkoh, Iruma
Saitama, 358

1998 total net sales: $110,465,640 Net income: $11,595,419

Y-E Data is a spin-off of Yaskawa Electric, a diversified manufacturer of heavy electric, factory automation and data processing equipment. Data processing products are the responsibility of Y-E Data, which first manufactured 8" one sided floppy drives in 1974 under an Orbis license. In addition to its drive manufacturing activities, Y-E Data supplies drive kits to manufacturers in India, mainland China and other Asian countries.

Y-E Data became an early leader in the Japanese OEM markets for both 8" and 5.25" two sided drives. Y-E Data also cooperated with NTT on the standard for 1.2 megabyte 5.25" drives and has been shipping its version since early 1982. Microfloppy drives were added in 1984. Y-E Data's biggest sale of all came in 1984, with IBM's selection of the firm's 1.2 megabyte 5.25" drive for use with the PC AT. In 1986, one inch high 3.5" drives were added to the product line. A 2.88 megabyte 3.5" microfloppy drive using cobalt modified oxide media was introduced in 1988 in an unsuccessful attempt to develop an industry standard. A 2.88 megabyte 3.5" drive using standard barium ferrite media was first shipped in 1990, but since discontinued with the decline in 2.88 megabyte drive shipments.

Y-E Data attempted to provide industry leadership in pioneering the market for high capacity floppy drives. A preliminary announcement of a 27.8 megabyte drive using metal particle media was made in 1989, with specifications revised in 1991. The final capacity specification became 20.8 megabytes, with initial shipments in late 1992, but the program was discontinued, due to low demand.

YUNG FU ELECTRICAL APPLIANCES CORP., LTD.
59 Ming Tsu Road, Section 2
Tainan
Taiwan

Marketing through Lxycon Enterprise Corporation, Yung Fu produces CD-ROM drives using purchased mechanisms. Production of the double speed unit began in late 1994, with faster drives following in later periods.

European Manufacturers

CALLUNA TECHNOLOGY LTD.
Blackwood Road, Eastfield
Glenrothes, Fife KY7 4NP
Scotland

1999 total net sales:$40,951,666 (FY ending 3/31/99) Net income: ($5,390,000)

Calluna Technology was founded to design and manufacture 1.8" drives in Glenrothes. The founders were all veterans of Rodime, the pioneer manufacturer of 3.5" drives, and many were previously with the Burroughs disk drive manufacturing facility in Glenrothes. Calluna occupied a new industrial building in 1992 and started production of disk drives in PC Card Type III format in mid-1993.

The PC Card drive product line has since been expanded, and currently includes drives with capacities up to 1,040 megabytes and an announced Type II 260 megabyte drive currently planned for production in mid-1999. In March, 1999, Calluna announced that the Type II drive will be produced in Singapore under a contract manufacturing arrangement with PCS, Inc., a California headquarted supplier of disk drive service and manufacturing programs. Production of a 520 megabyte Type III drive was initiated in 1997, utilizing a contract manufacturing arrangement with Xyratrex, the firm which resulted from a management buyout of IBM's manufacturing facilities at Havant, U.K., but other arrangements are expected to be made, since Xyratex plans to cease contract manufacturing of disk drives.

NOMAI
188, rue de la liberte – B.P. 141
50301 AVRANCHES cedex
France

Nomai entered the data storage market in 1992 as a manufacturer and marketer of rigid disk drive cartridges compatible with SyQuest 5.25" drives. After a flurry of legal actions by SyQuest were settled, Nomai was successful in setting up extensive distribution for the disk cartridge product line, including the temporary enlistment of Iomega as a reseller. In 1995, the company announced the development of 3.5" rigid disk cartridge drives, with initial shipments starting at the end of 1995. The basic 540 megabyte drive design was done in Scotland by Myrica (U.K.) Limited, a design firm staffed with Rodime graduates, with technology assistance from universities in the U.K. and France. The 540 megabyte drive and a later 750 megabyte model were manufactured by Xyratex at Havant in the U.K. Nomai also initiated a resale program for CD-RW drives during recent years.

During the 1997-98 period, claims and counterclaims between Nomai and Iomega appeared in the courtrooms of several countries, as Nomai entered the market for Zip compatible 3.5" floppy disk cartridges. Iomega cleared up the legal problems by buying control of Nomai and installing its own management. Subsequently, Nomai withdrew from the rigid disk cartridge drive business and has remained active in reselling CD-RW drives, a program since expanded to a worldwide basis by Iomega.

NEW ATG SA
1270 Avenue General Eisenhower
31047 Toulouse
France

Beginning as the optical disk operation of Thomson-CSF, ATG was formed as a joint venture in 1984 when CIT-Alcatel, a maker of image processing systems, was combined with Thomson-CSF, Rhone-Poulenc, Bull, and several other French companies to form Alcatel-Thomson-Gigadisc. Drive and media production began in Toulouse in early 1986. ATG was one of the first firms to get into production of optical drives, but media shortages hampered its growth. Disappointing sales caused Alcatel to decide to withdraw from the venture, and for a short time ATG was dormant while new investors were found. Officially renamed Art Tech Gigadisc, the firm became known as ATG Gigadisc.

In 1993, ATG Gigadisc purchased Cygnet Systems, reorganizing as ATG Cygnet, with the major portion of ownership held by Credit Lyonnaise, a French financial institution. Further reorganization in 1995 divided the organization into ATG Cygnet, Inc., and ATG SA, which produced drives and media, and also marketed ATG Cygnet libraries in Europe. The company had difficulty in achieving financial stability, and entered "judicial review" status, the French equivalent of Chapter 11. In late 1996, the firm sold the Cygnet operations to Dynatek Automation, and modified its corporate name to ATG S.A. in mid-1997. In early 1999, the company, once again in receivership, was acquired by New Medias Diffusion, one of ATG's distributors.

ATG products now include 12" write-once drives with up to 5.1 gigabytes per side capacity, plus a library storage unit containing a drive and six 12" disks. A dual head 16 gigabyte 12" WORM drive, scheduled for production in late 1996, is now scheduled for 1999 shipment, as is a redesigned six disk 12" optical library unit.

N. V. PHILIPS (See also Plasmon LMS)
5600 MD Eindhoven
The Netherlands

1998 total net sales: $33,900,000,000 Net income: $6,736,868,600

The Philips organization, established in 1891 as a manufacturer of electrical equipment, has been active for many years in the development of optically based information systems. Initial development work was spun off to joint ventures with Control Data. Philips' initial digital optical developments were a 12" write-once drive and the CD-ROM.

Philips, together with Sony, has been instrumental in establishing standards for CD and CD-ROM drives. The Philips CD-ROM has the distinction of being the first CD-ROM to be accepted by a major system OEM. Digital Equipment Corporation offered it as a peripheral on its MicroVax line. Philips and Sony provided a series of standards for CD-ROM, including CD-I and CD-ROM XA. Philips, along with Sony and others, is also a major sponsor of the DVD+RW format.

Manufacturing of CD-ROM drives, CD-R/RW drives (and mechanisms) is the responsibility of Philips Components, which sells large quantities of mechanisms to CD-ROM drive producers, some of which manufacture complete drives for resale under the Philips label. Drives are also provided to other Philips divisions for resale.

Philips began volume shipments of CD-I players in mid-1992. In 1992, the firm also began sales of CD-ROM drive subsystems bundled with software. CD-R drives began shipping in 1992 and Philips is currently one of the leading manufacturers of CD-R and CD-RW drives. In mid-1998, Philips and Mitsumi announced a joint development effort aimed at advanced CD-RW and DVD-ROM drives.

Philips developed MO disk drives for several years, but the company never made a major commitment to products employing MO technology, although Philips supplied 3.5" MO disk drive mechanisms for other manufacturers for a few years.

In 1985, Philips entered into a joint venture with DuPont, named Philips and DuPont Optical (PDO), to produce optical media of various types in large quantities. PDO did not meet financial expectations and was put up for sale in late 1990. The CD-ROM portion of PDO was sold to Disc Manufacturing, Inc. in mid-1991. Mitsubishi Kasei acquired U.S. manufacturing and marketing operations for plastic substrate writable media, while the remainder of PDO, including European marketing and the manufacture of 3.5", 5.25" and 12" glass substrate media, was retained by Philips.

In 1986, OSI, a joint venture between Philips and Control Data, was reorganized as Laser Magnetic Storage and charged with the responsibility of manufacturing and marketing the Philips CD-ROM, write-once optical disk drives designed by OSI using Philips-developed technology, and magnetic tape drives previously produced by another CDC joint venture. Philips owned 51% of LMSI while Control Data held the other 49%. In 1990, Philips purchased Control Data's share and became the sole owner of LMSI, renamed as Philips LMS and discussed separately below. Plasmon PLC purchased Philips LMS in early 1999, operating it as a subsidiary, Plasmon LMS.

PLASMON LMS
Subsidiary of Plasmon Plc
4425 ArrowsWest Drive
Colorado Springs, CO 80907

LMSI was formed in 1986 through the combination of Optical Storage International, Computer Peripherals International, and Philips' CD-ROM operations. Philips owned 51% of the company. CPI was a Control Data and NCR joint venture that produced tape drives. OSI, formed in 1984, was a joint venture of Philips and Control Data. The organization originally was managed by Control Data and combined two earlier joint ventures, Optical Peripherals Laboratory in Colorado and Optical Media Laboratory in the Netherlands. The entire U.S. operation, at one time split between California and Colorado, was consolidated at the Colorado facility in 1986. In 1986, Philips assumed management responsibility for LMSI and in 1990 purchased Control Data's interest. In 1992, LMSI was placed in the Philips Technologies Group and received new senior management. The firm was renamed Philips LMS in 1994. In early 1999, Philips LMS was sold to Plasmon PLC for $26.4 million and renamed Plasmon LMS, continuing to operate in Colorado Springs as a wholly owned subsidiary. Media is obtained from a Plasmon LMS manufacturing operation at Blackburn in the UK, obtained from Philips as part of the purchase of Philips LMS. In July, 1999 Plasmon PLC announced it had acquired the 12" optical library business of Cygnet Storage Solutions. Cygnet will continue to manufacture the libraries as a subcontractor throughout the remainder of 1999.

Plasmon LMS currently makes 12" optical disk drives, 12" optical disk libraries, and also produces magnetic tape drives. A 5.25" write-once drive, introduced in 1987, was discontinued after a few years.

In 1990, the company introduced the first optical disk drive with two independently operating heads scanning both sides of the disk media. The drive uses 12" media and is available as a freestanding disk drive or as part of a jukebox unit containing the drive and five or six disks. Production of the 12" products was delayed until the latter part of 1991, and production was sporadic until late 1992 when the manufacturing process was stabilized.

DISK/TREND ON DISK

1999 DISK/TREND REPORT

DISK/TREND ON DISK

Introduction

DISK/TREND ON DISK is a licensed set of floppy disks available for separate purchase that contain the statistical tables and specification tables from the annual DISK/TREND Reports. The statistical tables are provided in text format usable on IBM-compatible computers running under MS-DOS, PC-DOS, or Microsoft Windows. Specification tables are provided in the form of an Excel spreadsheet file.

User instructions for 1999 DISK/TREND on Disk are included on the data diskettes in the form of web browser readable files, and can also be found on the DISK/TREND web site at www.disktrend.com/dtod/dtod.htm. To locate the user instructions on the diskette, set the browser to: file://A:/index.htm. If you are using other than the "A" drive as your floppy disk, then use the appropriate drive letter.

If you are using DISK/TREND on Disk files for years earlier than 1999, please refer to the DISK/TREND Report for the appropriate year and product type for instructions.

A file translation program, DataImport, is available from DISK/TREND to assist in converting the data supplied to the formats of several popular spreadsheets. One copy of DataImport is provided at no extra charge to DISK/TREND subscribers who purchase DISK/TREND on DISK for the first time. Upgrades to DataImport for users with the earlier AutoImport conversion software are available at a special price. Please contact DISK/TREND for details.