QUANTUM

CORPORATION

BUSINESS PLAN

APPENDIX

APRIL 1980

Dave Brown

APPENDIX

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APPENDIX I

MARKET BACKGROUND

Winchester boom to broaden

ANDREW ROMAN, Roman Associates International

Worldwide market for 14-inch drives to top $2.6 billion by 1984, while shipments of 8-inch units will grow at more than 100 percent annually

The mushrooming market for small-to-medium-sized computer systems in applications ranging from accounting, payroll and inventory in small businesses to distributed data processing has created a booming demand for Winchester disk drives as part of these systems. The requirement for small data bases—20M bytes or less—prompted the advent of the 8-in. Winchester drive, while medium-to-large systems—requiring 100M to 600M bytes or more of mass storage—account for most of the 14-in. Winchester drives.

And the widening use of Winchester drives in the late 1970s can only continue to unfold in this decade. The worldwide market for 14-in. Winchester drives in 1979 was 124,000 spindles, valued at $1.352 billion. Those figures will jump to 253,000 spindles and $2.687 billion, respectively, by 1984—a compounded annual growth rate of 15 percent in shipments of both units and dollars.

Similarly, worldwide shipments of 8-in. Winchester disk drives will increase from a projected 1980 level of 102,000 drives, valued at $590.2 million, to a 1984 level of 544,000 spindles, valued at $1.729 billion. Compounded annual growth rates for 8-in. Winchester unit

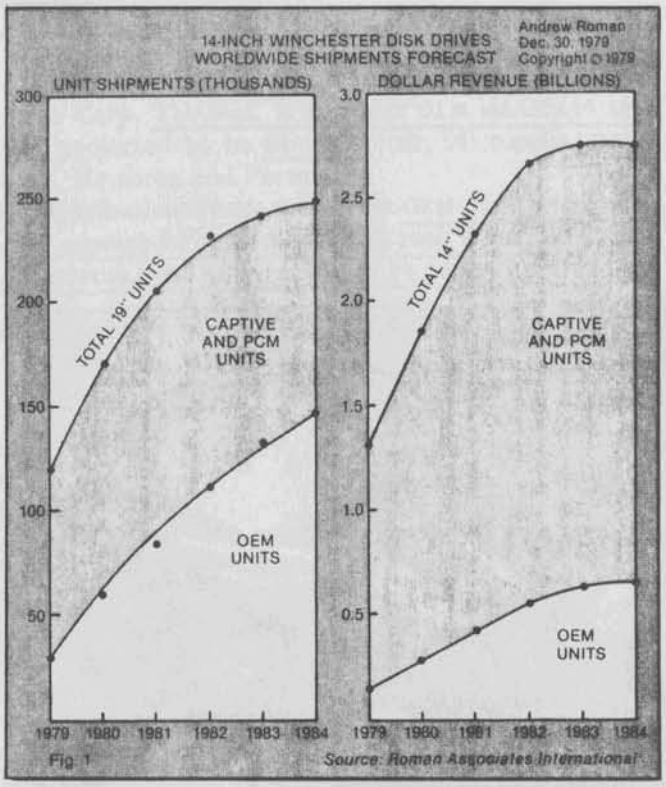


Fig. 1. Forecast shows *shipments of 14-in. Winchester disk drives approaching 250,000 units, worth $2.68 billion, by 1984.*

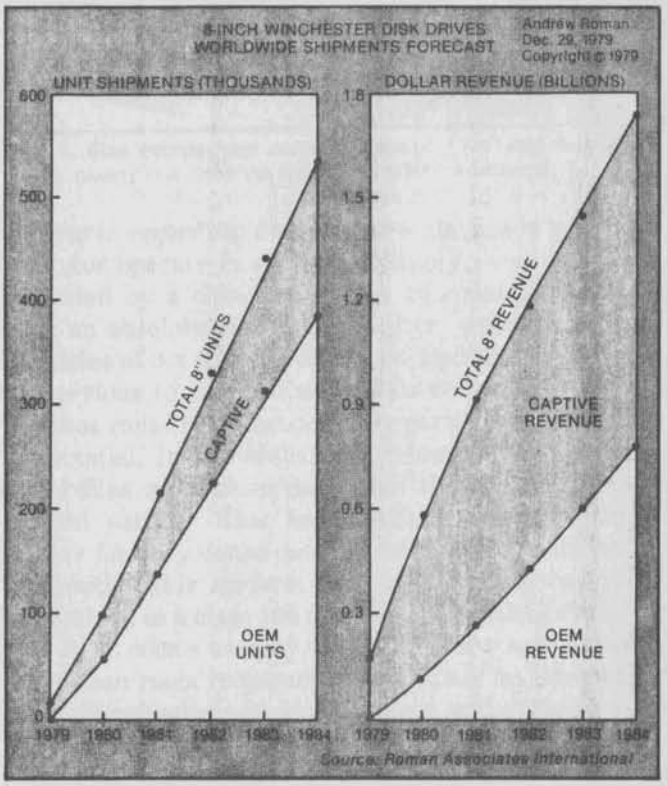


Fig. 2. Total shipments *of 8-in. Winchester drives will top 500,000, with a value of almost $1.8 billion, by 1984.*

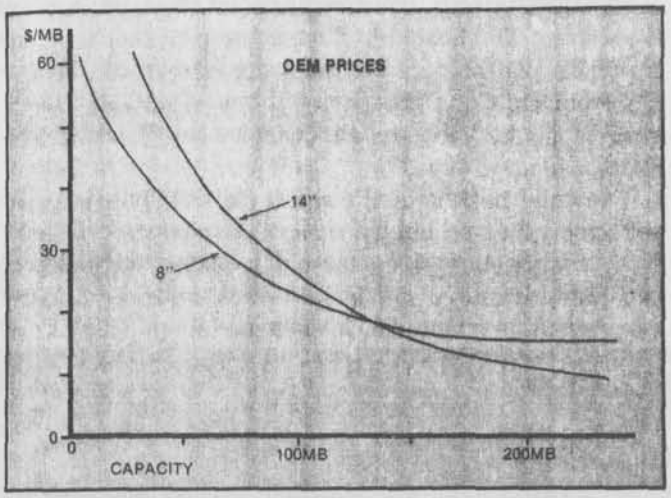


Fig. 3. OEM price curve *shows that 8-in. drives are more cost-effective than 14-in. units for capacities less than 100M bytes.*

shipments are 101.2 percent, with revenue growth of 58.6 percent—slightly lower because of anticipated average price decreases.

Only three manufacturers shared in the 1979 8-in. Winchester drive market: IBM, with an estimated 13,600 units, International Memories Inc. and BASF, with a combined total of 2900 units. It is, then, more relevant to forecast 1980 shipments for the 8-in. Winchester drive market.

The OEM Winchester market

The OEM market for Winchester disk drives is growing at a compounded annual growth rate of 38 percent for 14-in. drives and 167 percent for 8-in. drives. Besides IBM, market leaders for 1979, ranked in order of number of spindles shipped for 14-in. Winchester drives, are Storage Technology Corp., Memorex, CDC/MPI, Shugart, Okidata and Century Data Corp. The 8-in. Winchester OEM leaders in 1980 are projected to be Shugart, IMI, Micropolis, BASF, CDC, Memorex and Pertec.

Distribution trends show that OEM market channels will account for 43 percent of all 1980 Winchester drive shipments, and will increase to 70 percent by 1984. By that same year, 80 percent of all moving head rigid magnetic disk drives will be Winchester-type fixed disks, representing an increase of 100 percent, or double 1979's worldwide Winchester shipments.

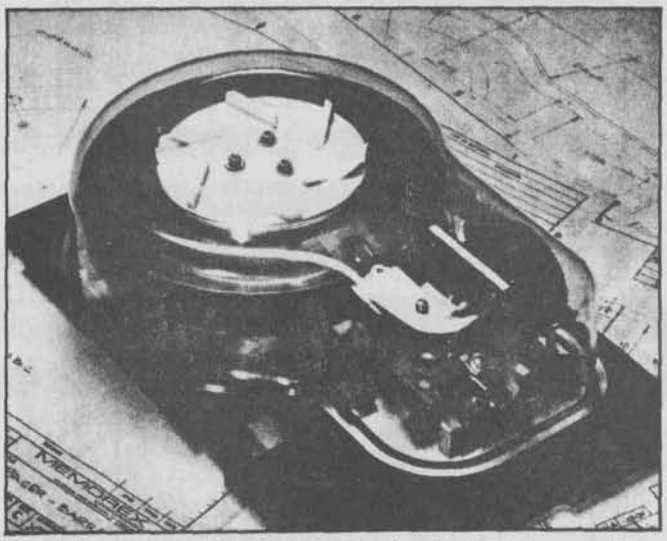


Fig. 4. Memorex model 101 *8-in. drive has 11.7M-byte capacity.*

Shipments of microcomputers, minicomputers and mainframes, growing at 30 percent annually, are causing the explosive demand for Winchester disk drives. The largest applications for Winchesters are in small and medium business and commerical computer systems, distributed data processing and general-purpose applications. These include science, economics, government and manufacturing, which require reliable, direct access storage devices (DASD), such as Winchesters.

Winchester technology

The essence of Winchester technology is that the head-to-disk assembly (HDA) of Winchester disks is sealed from outside air and is non-removable. The magnetic recording disks, read/write heads and head actuator operate in a contamination-free environment provided by a closed-loop filter to equalize pressure, plus an absolute recirculation filter, which arrests all particles of 0.3 microns or larger. Because the drive is impervious to external air and its contaminants, head crashes caused by dust and dirt particles are virtually eliminated. In this sealed environment, the read/write head flies 20 micro-inches from the magnetic oxide-coated surface. This head-to-disk surface proximity allows for very dense data-bit and track density on the magnetic oxide surface. This HDA module has to be assembled in a class 100 clean room, which is similar to the clean rooms used by semiconductor manufacturers. The clean room requirement is a costly investment for new Winchester market entrants and, therefore, a barrier to competing in the Winchester business.

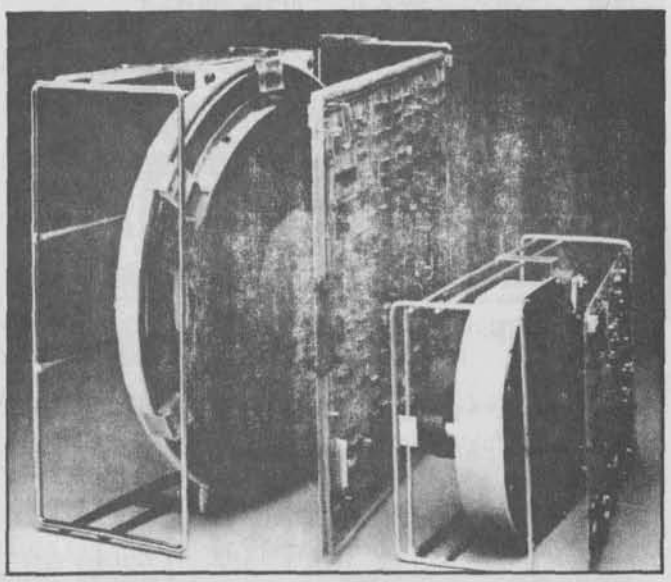


Fig. 5. Size comparison *between Priam's 14-in. and 8-in. (right) drives clearly illustrates the smaller drive's compactness.*

During read/write/seek operations, the Winchester head flies 20 micro-inches above the surface on an air bearing, supported by carefully balanced aerodynamic

Unit shipments of 8-in. Winchester drives will increase fivefold by 1984, to 544,000 spindles.

forces. The head rests on a silicone-lubricated landing zone during starts and stops. When the disk is not spinning, the head rests on and actually contacts the takeoff and landing zone on the disk. When flying, the head is loaded with a light force of 10 grams. This head loading and unloading task has to be solved reliably and economically to achieve media removability in Winchester drives. The head will have to be retracted so that the disk platter can be removed from the spindle. Control Data Corp. is reported to be working on such a concept in the yet-to-be-announced 8-in. "Lark" drive (MMS, January, p. 40).

The chief benefit of Winchester disk drives is their extremely high reliability, measured in an MTBF of 8000 hrs., compared to 4000 for older 3330-II technology. Another advantage of Winchesters is that they require no preventive maintenance, such as changing air filters

MANUFACTURERS OF WINCHESTER DISK DRIVES

U.S. MANUFACTURERS	8-IN. WINCHESTER DRIVES					
	0 to 40M Bytes			Over 40M Bytes		
	ANNOUNCED	NOW SHIPPING	EXPECT TO ANNOUNCE	ANNOUNCED	NOW SHIPPING	EXPECT TO ANNOUNCE
Ampex Memory Products Div.						
Ball Computer Products, Inc.			X			
Burroughs Corp.						
Century Data Systems, Inc.			X			
Control Data Corp.			X			X
Dastek Corp.						
Data General Corp.						
Data Peripherals, Inc.			X			
Datapoint Corp.			X			
Digital Equipment Corp.			X			
Hewlett-Packard Co.			X			
IBM Corp.		X			X	
International Memories, Inc.		X				
ISS/Univac						
Kennedy Co.		X				
Memorex Corp.		X				
Microcomputer Systems Corp.			X			X
Microdata Corp.						
Micropolis Corp.		X			X	
New World Computer Co., Inc.		X				
Okidata Corp.						
Pertec Computer Corp.	X					
Priam Corp.	X					
Shugart Associates		X				
Storage Technology Corp.			X			
JAPANESE MANUFACTURERS						
Fujitsu America, Inc.			X			
Hitachi America Ltd.			X			
Mitsubishi Electric Corp.			X			
NEC Information Systems, Inc.			X			X
Nippon Peripherals Ltd.						
Toshiba Corp.						
EUROPEAN MANUFACTURERS						
BASF Systems		X				
Cii Honeywell Bull						
Computer Peripherie Technik, GMBH				X		
Data Recording Equipment Ltd.			X			
Philips Data Systems BV						
Siemens Corp.						

*Special 10.5-in. disk

SOURCE: Roman Associates International

or cleaning and aligning heads. Winchester technology also yields lowest cost per byte stored and lowest cost per function, highest storage capacity (cost-effective storage capacity) and lowest cost of moving-head rigid magnetic disk drives. Because the media cannot be removed by the operator, there's no need for head-alignment procedures as there is with other disk drives, nor are there any costly head-access and load/unload devices, links, levers, solenoids or other mechanisms required for disk-pack interchangeability.

Today's Winchester drives use conventional magnetic oxide media and ferrite read/write heads. The next-generation Winchester technology will employ thin-film, heads, and, in a second phase, thin-film media. Thin-film heads can resolve track densities at more than 1000 tpi and bit densities greater than 12,000 bpi using conventional ferrous oxide film-coated disk media, without going to plated or sputtered thin-film disks. The resulting bit density (tpi × bpi) will be 1.2×10^7 bits per square inch—an order of magnitude higher than today's Winchesters, which have bit densities of 6×10^6 bits per square inch. Last October, IBM made its first customer shipments of a 3370 thin-film-head disk drive of 571M-bytes per spindle, two spindles per drive. Expected to be announced in mid-1980 is the much-heralded Whitney drive, the 3380, which is expected to offer twice the storage capacity of the 3370.

14-IN. WINCHESTER DRIVES			
0 to 100M Bytes	101M to 300M Bytes	301M to 500M Bytes	Over 500M Bytes
	X		
X			
X	TBA		
X	X	X	X
	X	X	
X	TBA		
TBA			
X			
X	X	X	X
X	X	X	X
X	TBA		
X	X		
X	X		
X	X		
X	X		
X	TBA		
X			
X	X	X	X
X	X	X	X
X	X	X	X
X	X		
X	X	X	TBA
X	X	X	
X			
X			
X	X		
TBA	TBA		
X			
			X

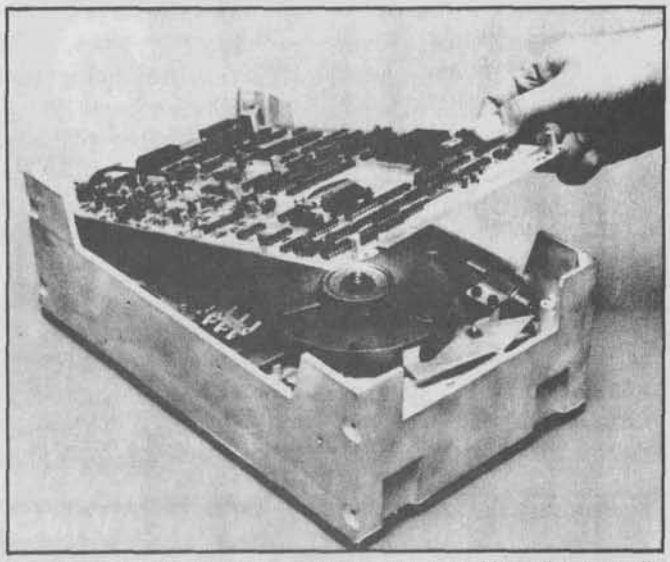


Fig. 6. Electronics section *of Micropolis 8-in. Microdisk is easily accessible.*

Why 8-inch Winchesters?

Increased track and bit densities in recent years have combined to yield a storage capacity of 40M bytes or more per 14-inch disk surface. The Memorex 3652 and the Storage Technology Corp. 8652, for example, store 635M bytes on 15 data surfaces. Many small business computers do not require such high storage on one data surface nor so much data under one head. Applications in which smaller data bases are needed—desk-top computers, microcomputers, distributed data-processing minicomputers—can't justify the cost of so much storage. The requirement spawned development of the 8-in. Winchester disk drive, which provides a much more cost-effective price/performance alternative.

The 8-in. disk is most suitable for storage requirements of less than 100M bytes (Fig. 3). A large shift of users to 8-in. drives will occur in the first half of the 1980s. But because the Winchester market is driven both by technology and market considerations, technology advancements will continue to drive track and bit densities higher, resulting in more storage than is affordable for some applications. During the middle of

The smaller 8-in. drives get the nod for data base requirements generally from 5M bytes to as much as 200M bytes.

the decade, the industry will see the introduction of an even smaller moving-head rigid disk, probably in a 5¼-in.-diameter format. This will cause a shift to the right of the crossover point illustrated in Fig. 3. Manufacturers are already developing such a drive.

Current 8-in. Winchester developments have resulted in some non-standard disk diameter sizes, with seven of the 10 manufacturers currently shipping 8-in. drives using 200-mm. diameter platters, and three, including IBM, adopting 210-mm. diameter platters. The 200-mm diameter offers an advantage in the mechanical mounting and packaging envelope, but loses IBM compatibility. There are also some variations in the inner disk diameter.

Small is desirable

As hardware boxes are adapted to desk-top configurations in the office, the computer is also moving out of the traditional EDP room and into the office. This move demands that the Winchester disk drive improve. It must be safer, lighter and quieter; it must also consume less energy, be less bulky and blend with the decor of other office machines. The 8-in. and smaller Winchester drives offer all these features.

In addition, 8-in. Winchester drives offer cost-effective maintenance because the complete device can be replaced. With the increased use of microprocessors, more self-diagnostic electronics will reside within the disk drive, enabling the operator to troubleshoot and replace the drive.

Because the cost of electronics is dropping faster

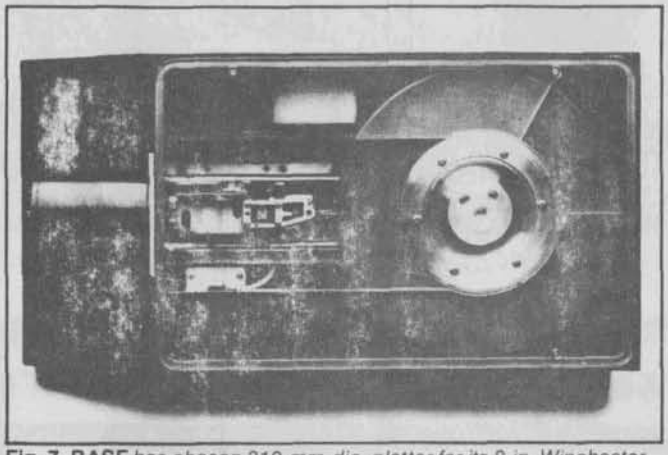


Fig. 7. BASF *has chosen 210-mm-dia. platter for its 8-in. Winchester.*

8-INCH WINCHESTER DRIVES

MANUFACTURER	MODEL NUMBER	TOTAL CAPACITY (megabytes)	NUMBER OF DISKS/ DIAMETER (mm.)	BYTES PER TRACK	TRACKS PER IN. (tpi)/ BITS PER IN. (bpi)
BASF Systems	6171	8	1/210	13,344	500/6542
Computer Peripherie Technik GMBH	HT-40	41	3/200	20,160	295/10,300
IBM Corp.	4963, PIC 0110	64	6/210	16,384	450/8530
International Memories, Inc.	7710	11	2/200	10,800	300/5868
Kennedy Co.	7000	12	2/210	11,520	300/5280
Memorex Corp.	101	11.7	4/200	12,000	195/6100
Micropolis Corp.	1223-1	35.6	2/200	12,288	478/8750
New World Computer Co., Inc.	211	2.1	1/200	13,351	100/8000
Pertec Computer Corp.	D-8000	20	2/210	14,400	476/6688
Priam Corp.	2050	20	2/200	13,308	480/6370
Shugart Associates	SA-1002	5.35	1/200	10,400	172/6270

than the cost of Winchester drives, disk controller cost is becoming a smaller part of the total Winchester system cost. During the eighties, manufacturers will implement more controller functions into the Winchester drive itself. Microprocessors will further augment the functions of Winchester disk drive systems, creating intelligent disk drives, such as the CDS Marksman, the STC 2700, the Shugart 4000 series, the ISS/Univac 7350 and the Locust.

Intelligence means that the drive, in some cases without host CPU control, can provide disk control functions, such as speeding the drive up or slowing it down during startup or shutdown; seeking assigned cylinders and data tracks, data encoding or decoding; and providing data format options, data buffering, on-board diagnostics and maintenance facilities.

Head access and control techniques for Winchester disks also offer cost-effective variations: open-loop servo and closed-loop servo control. Under the open-loop servo method being used by Shugart and Memorex, every disk surface is a recording data surface. Because it is a low-cost method, the 8-in. drive also costs less. Under open-loop, there is no feedback transducer element to tell where the head is. A stepper motor provides this information.

Under closed-loop servo, one dedicated surface has prerecorded servo data permanently written on it by the disk manufacturer, making this surface unavailable for data storage. This method also provides precise position feedback data, but it is more expensive.

As track densities increase in the 1980s, the use of track-embedded servo control systems will grow. With this method, the servo feed-back positioning information is recorded digitally on each data track, between the data sectors on the surface of each magnetic disk platter. The trade-offs are that there is a fixed sector per track and the recorded data format is set at a fixed

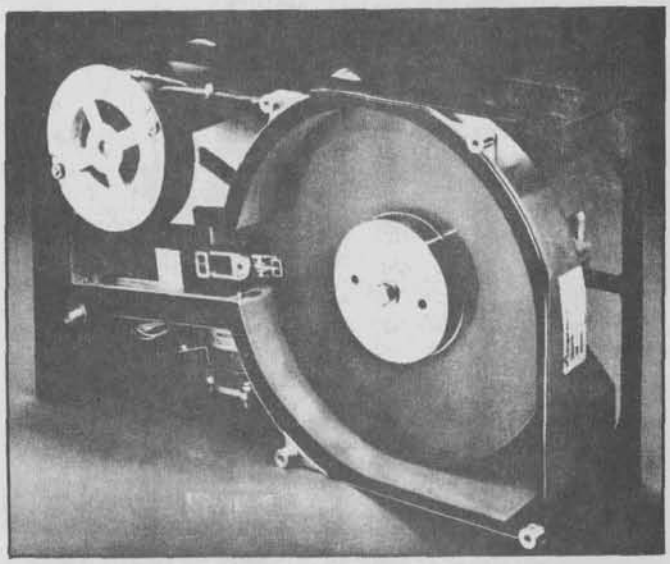


Fig. 8. Shugart's SA1004 *8-in. drive uses a stepper motor.*

AVERAGE POSITIONING TIME (msec.)	ACTUATOR TYPE	DATA TRANSFER RATE (kilobytes/sec.)	INTERFACE TYPE	PRICE (single-unit/OEM)	COMMENTS
50	linear voice coil	800	SMD	$2100	three OEM interfaces and a 24M-byte version (model 3330) are available
15	rotary	1209	SMD		plated disks
27	swing arm	1031	Series/1		S/34, 4300 and 8100 versions available
50	linear voice coil	648	floppy		track-following servo; 20M-byte version coming
50	rotary	687.5	OEM	$2300/$1840	4M- and 20M-byte versions available
70	band stepper	593	floppy	$1900/$1560	family of drives without power supplies; floppy-compatible mounting envelope and interface
34	rotary	922	OEM, S-100 bus		7M- and 21M-byte versions available; can be GCR encoded for capacities of 9M, 27M or 45M bytes
18.8	fixed head	756.5	OEM	$3000/$1200	not a sealed Winchester, but a unique head-per-track disk using 8-in. media
50	rotary	870	floppy	$3000/$1800	floppy-compatible mounting envelope
50	linear voice coil	1030	floppy	$1500 (OEM)	floppy-compatible mounting; I/O compatible with 14-in. disks; 33M- and 66M-byte versions available
70	band stepper	542.5	floppy	$1800/$1140	floppy-compatible mounting envelope and interface; 10.67M-byte version available

14-INCH WINCHESTER DRIVES

MANUFACTURER	MODEL NUMBER	TOTAL CAPACITY (megabytes)	NUMBER OF DISKS	BYTES PER TRACK	TRACKS PER IN. (tpi)/ BITS PER IN. (bpi)
Ampex Corp.	9150	158	4	20,160	478/6370
BASF Systems	6150	42	2	20,160	300/6380
Burroughs Corp.	FD 214	80	4	58,256	300/5500
Century Data Systems, Inc.	Marksman M-40	40	2	24,000	182/7545
CII Honeywell Bull	D168	120	4	19,200	600/7300
Control Data Corp.	9730-48	48	2	20,160	340/6220
	9730-80	83	3	20,160	340/6220
	9730-160	166	3	20,160	680/6220
	33801	317.5	8	19,069	600/6425
	33502	635	12	19,069	600/6425
Dastek Corp.	4835	398.2	4	40,320	685/12772
Data General Corp.	6105	25	2	16,384	166/5946
Fujitsu America Ltd.	F6411	135	3	16,736	668/5694
	F496	635	11	19,069	668/6426
	F493	317.5	8	19,069	480/6362
	M2284	165	3	20,480	668/6580
	M2253	50	2	20,480	300/6230
Hewlett-Packard Co.	7910	12	1	8192	300/3225
Hitachi America Ltd.	MFD-135F	6.5	2	14,500	48/5241
	DK62-80	86.6	4	15,360	300/5570
IBM Corp.	3340	70	3	16,736	300/5636
	3350	317.5	8	19,069	478/6425
	3370	571	TBA	TBA	TBA/TBA
ISS/Univac	717	154	4	19,968	476/6366
	735	354	8	21,060	476/6714
	7350	317.5	8	19,069	480/6425
Kennedy Co.	5303-70	70	3	20,160	300/6000
Memorex Corp.	612	84	3	20,160	300/6350
	601-75	75	3	17,960	300/5636
	602	150	3	17,960	600/5636
	3650	317.5	8	19,069	480/6425
	3652	635	8	19,069	935/6350
Microcomputer Systems Corp.	MSC5900	87.8	4	17,920	300/5636
Microdata Corp.	7503	63	3	17,920	300/5636
	Reflex-II	157	4	19,968	478/6367
Mitsubishi Electric Corp.	M2884-61	130.1	4	20,160	460/6122

AVERAGE POSITIONING TIME (msec.)	ACTUATOR TYPE	DATA TRANSFER RATE (kilobytes/sec.)	INTERFACE TYPE	PRICE (single-unit/OEM)	COMMENTS
30	rotary	1209	SMD		
50.1	rotary	1000	OEM		
45	rotary	568	compatible with MD 122 floppy	less than $4000	rack mount and power supply optional
43	band stepper	960	microprocessor based		open-loop servo; power supply not included; intelligent version also available
40	linear voice coil	920	OEM		special 10.5-in. disk; track-embedded servo; thin-film heads; also available in 60M- and 90M-byte versions
30		1209	SMD		
30		1209	SMD	$5300/$4300	.96M- or 1.93M-byte fixed-head option available
30		1209	SMD		.96M- or 1.93M-byte fixed-head option
25		1198	IBM 3350		3350 plug-compatible; 1.72M-byte fixed-head option
25		1198	IBM 3350	$50,520	1.72M-byte fixed-head and dual-port options available
28	linear voice coil	2000	SMD		first 3370-type OEM drive; 200M- and 332M-byte versions available
60	stepper	910	custom Data General	$8100	for DG Nova and Eclipse systems
27		885	SMD		
20		1198	IBM		twice the capacity of an IBM 3350
20		1198	IBM		
27		1011	SMD		OEM version; 0.66M-byte fixed-head option available
40		819	SMD		OEM version; .33M- or .66M-byte fixed head option available
70		526	HP		for HP 3000 series
100	stepper	875	OEM		21K-byte fixed-head option
37		869	OEM		144K-byte fixed-head option
25		859	IBM		for System 370, S/7, S/3, 303X series and 4341
25		1198	IBM		for System 370; 1.14M-byte fixed-head version
20		1859	IBM		for 4300 series; uses dual actuator, thin-film heads and dual-spindle drive
35		1198	SMD		Locust model; 1.2M-byte fixed-head option available
23		1260	SMD		
25		1198	IBM		for Univac and Itel PCM market
45		1000	SMD	$4200/$3360	
32		1209	SMD		
32		885	SMD	$5325/$4325	OEM model
32		885	SMD		OEM model
25		1198	IBM		plug-compatible with IBM 3350
22		1198	IBM		twice the capacity of an IBM 3350; 2.3M-byte fixed-head option available
40		885	SMD		includes a ¼-in. cartridge tape drive tied to the disk spindle for backup
30		885	SMD		0.54M-byte fixed-head option available
30		1175	SMD		1.2M-byte fixed-head option available
38	rotary	896	SMD	$4900/$4687	rotary motor with power supply; uses 3350 technology; 0.81M-byte fixed-head option

MANUFACTURER	MODEL NUMBER	TOTAL CAPACITY (megabytes)	NUMBER OF DISKS	BYTES PER TRACK	TRACKS PER IN. (tpi)/ BITS PER IN. (bpi)
NEC Information Systems, Inc.	1240	83.1	3	19,968	480/6370
	N7751	317.5	8	19,069	480/6400
Nippon Peripherals Ltd.	NP-24	280	8	16,736	480/5636
	NP-25	317.5	8	19,069	480/6425
Philips Data Systems BV	X1220	20		14,592	300/6540
Priam Corp.	DISKOS 3350	33.2	1	19,968	480/6370
Shugart Associates	SA4008	29	2	18,000	172/5534
Siemens Corp.	PS5-8	517.1	10	20,160	590/6060
Storage Technology Corp.	2720	200	4	18,432	555/6706
	8350	317.5	8	19,069	480/6425
	8650	635	8	19,069	957/6425
Toshiba Corp.	MK300F	36	2	16,384	318/5940

number of bytes per block. Possible storage inefficiency could result. Also, the magnetic platter media is not an industry standard and, therefore, not easily available from several suppliers at a low cost.

Alternatives to Winchester disk drives include charge coupled devices (CCDs), magnetic bubble memories (MBMs) and the recently introduced optical disk memories. Some of these provide faster access, and some have much higher capacities, but none can compete effectively on a cost/performance or cost-per-function basis with moving-head rigid magnetic disks, such as Winchesters. Optical disks, such as those offered by Philips under the Magnavox brand, claim a 6000M-byte capacity on one side of a 12-in. disk. But the data stored on optical disks is not alterable; data written on a track cannot be erased and updated on the same spot.

Magnetic bubble memories will challenge floppies in the low end and be used in intelligent terminal

REFERENCE LITERATURE

For more information on the Winchester disk drives surveyed in this article, use the reader circle numbers listed below.

Company	Circle No.
Ampex Corp., El Segundo, Calif	241
Ball Computer Products, Inc., Sunnyvale, Calif.	242
BASF Systems, Bedford, Mass.	243
Burroughs Corp., Detroit, Mich.	244
Century Data Systems, Inc., Anaheim, Calif.	245
CII Honeywell Bull, Waltham, Mass.	246
Computer Peripherie Technik GMBH, Berlin, W. Germany	247
Control Data Corp., Minneapolis, Minn.	248
Dastek Corp., Los Gatos, Calif.	249
Data General Corp., Westboro, Mass.	250

AVERAGE POSITIONING TIME (msec.)	ACTUATOR TYPE	DATA TRANSFER RATE (kilobytes/sec.)	INTERFACE TYPE	PRICE (single-unit/OEM)	COMMENTS
40		1198			0.96M-byte fixed-head option available
20		1198	IBM		1.19M-byte fixed-head option and OEM version available
20		885	IBM		IBM 3344 plug compatible; 1.004M-byte fixed-head option available
20		1198	IBM		IBM 3350 plug compatible 1.144M-byte fixed-head option available
35	rotary	1305	SMD		track-embedded servo; 3340 technology
50		1030	SMD		66M- and 154M-byte versions also available
87	stepper	889	floppy	$3500/$2000	3340 technology; OEM model; 0.144M-byte fixed-head option available
20		806	SMD		3350 technology; 1.15M-byte fixed-head option available
25		768	SMD		3350 technology; OEM model
25		1198	IBM		IBM 3350 plug compatible; 1.14M-byte fixed-head option available
25		1198	IBM		IBM 3350 plug compatible; 1.14M-byte fixed-head option available
40		896	OEM		0.26M-byte fixed-head option available

Company	Circle No.
Data Recording Equipment Ltd., Middlesex, England	251
Datapoint Corp., San Antonio, Texas	252
Digital Equipment Corp., Maynard, Mass.	253
Fujitsu America, Inc., Santa Clara, Calif.	254
Hewlett-Packard Co., Boise, Idaho	255
Hitachi America Ltd., San Francisco, Calif.	256
IBM Corp., Armonk, N.Y.	257
International Memories, Inc., Cupertino, Calif.	258
ISS/Univac, Cupertino, Calif.	259
Kennedy Co., Monrovia, Calif.	260
Memorex Corp., Santa Clara, Calif.	261
Microcomputer Systems Corp., Sunnyvale, Calif.	262
Microdata Corp., Irvine, Calif.	263
Micropolis Corp., Canoga Park, Calif.	264
Mitsubishi Electric Corp., c/o NCL Data Inc., Santa Clara, Calif.	265
NEC Information Systems, Inc., Wellesley, Mass.	266
New World Computer Co., Inc., Costa Mesa, Calif.	267
Nippon Peripherals Ltd., Kanagawa-Ken, Japan	268
Okidata Corp., Mount Laurel, N.J.	270
Pertec Computer Corp., Chatsworth, Calif.	271
Philips Data Systems BV, Apeldorn, Netherlands	272
Priam Corp., San Jose, Calif.	273
Shugart Associates, Sunnyvale, Calif.	274
Siemens Corp., Iselin, N.J.	275
Storage Technology Corp., Louisville, Colo.	276
Toshiba Corp., Tokyo, Japan	277

The Winchester drive's chief asset is its reliability, with its MTBF of some 8000 hours.

applications because of their small size and relatively fast access and nonvolatility. However, because of their low capacity, MBMs will never seriously compete with Winchester disk drives.

With a charge-coupled device, stored data is volatile and, therefore, lost when device power is removed. CCDs have a much higher cost per function than Winchester disk drives. CCDs will be used as replacements for head-per-track disk drives or as cache memories for large Winchester-based disk systems. In this mode, CCDs will enhance Winchester drives, not compete as an alternative.

Backing up Winchester disk drives

If a sudden power out occurs in a Winchester disk-based system how is data base integrity insured? On larger Winchester disk-based systems, such as the Memorex 3652 and the STC 8652, half-inch magnetic tape is a primary backup device. An industry standard half-inch magnetic tape offers fast data transfer rate, high storage capacity and low storage cost per byte. It is not cost-effective for 8-in. Winchesters, however, because of its large box size and high cost per system—almost more than the 8-in. Winchester disk subsystem itself.

Several manufacturers now offer smaller tape cartridge and cassette drives with ANSI standard quarter-inch magnetic tape. These provide low device cost, small physical size and ease of use, but have low data transfer rate, low storage capacity and lack of industry standardization.

Floppy disk backup offers low system cost, small size, easy system integration, ease of use and industry standardization. But because they have low storage capacities and low data transfer rates, floppies are especially suitable to back up the Winchester drives used in the small data bases of desk-top computers and microcomputers.

The backup question still merits considerable attention from computer system and drive manufacturers alike, with various combinations being tried. But there seems little question that the surface has only been scratched in Winchester disk drive applications, with an increasing swing coming to the 8-in. and smaller units, especially as their storage capacities increase. ■

Andrew Roman is president of Roman Associates International, an independent marketing consulting firm in Newark, Calif., specializing in computer peripherals. He has prior product management and marketing management experience with Control Data Corp., Pertec Computer Corp., NCR and Diablo Systems, Inc.

Mini Winchester disk drives rush to the OEM market

A new eight-inch disk offering improvements in capacity and access time promises to become the dominant memory for small computer systems.

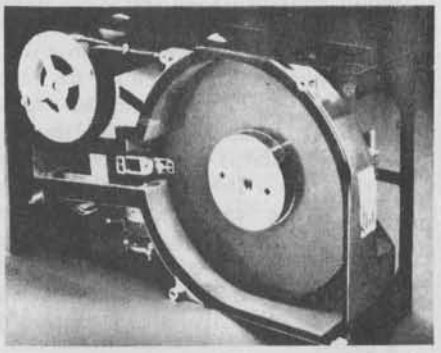
Seldom has a new product generated as much excitement in an industry already noted for rapid technological change as has the eight-inch Winchester disk for makers of minicomputer peripherals. While only one manufacturer, International Memories, Inc. (IMI) of Cupertino, Calif., is currently shipping eight-inch Winchesters to the OEM market, at least 10 others have announced their intention to enter that arena, half of them with products by year's end. "This has got to be an idea whose time has come," says independent consultant David E. Gold, a West Coast specialist in computers and peripherals.

"Winchesters"—IBM's pre-announcement code name for its Model 3350 disk drive—incorporate nonremovable (fixed) media packaged with a moving read/write head mechanism in a sealed module. Compared to removable disk technologies, Winchesters permit closer spacing between head and disk surfaces, so they offer higher capacities and faster access times. And because the modules are protected against dust and rough handling, Winchester drives are considered more reliable than removable media alternatives.

Winchester technology has been available since 1977 but never on disks smaller than 14 inches in diameter until early this year, when IBM announced the Model 3310 "Piccolo" eight-inch Winchester for its S/34 small-business system. The new smaller drives are equal in size to "floppy" disk drives—currently the most popular form of minicomputer direct access storage—yet can provide 10 to 30 times the capacity and better than one-twentieth the access time for less than twice the cost.

The sound of music

Piccolo music is sweet indeed. Consultant James Porter, an authority on rotating-media markets, estimates that by 1982 eight-inch Winchester drives will account for more than 60 percent of all fixed disk drives in the 30- to 200-megabyte range. The newly announced Piccolo-type drives hold less than 30 megabytes, but Porter expects even the under-30-megabyte fixed-disk market to grow at a 26 percent annual rate through 1982. Porter, whose "1979 Disk/Trend Report" is highly regarded by the industry, predicts worldwide total revenues to manufacturers of moving head, rigid (as opposed to floppy) disk drives to reach $6.3 billion in 1982, up from $3.5 billion in 1978. The share of worldwide revenues generated by fixed disk drives will be 66 percent in 1982, up from 44.5 percent in 1978.



***Shugart's small Winchesters** are priced significantly below the competition's. Shown here is the SA1000 10-megabyte drive with printed circuit board removed.*

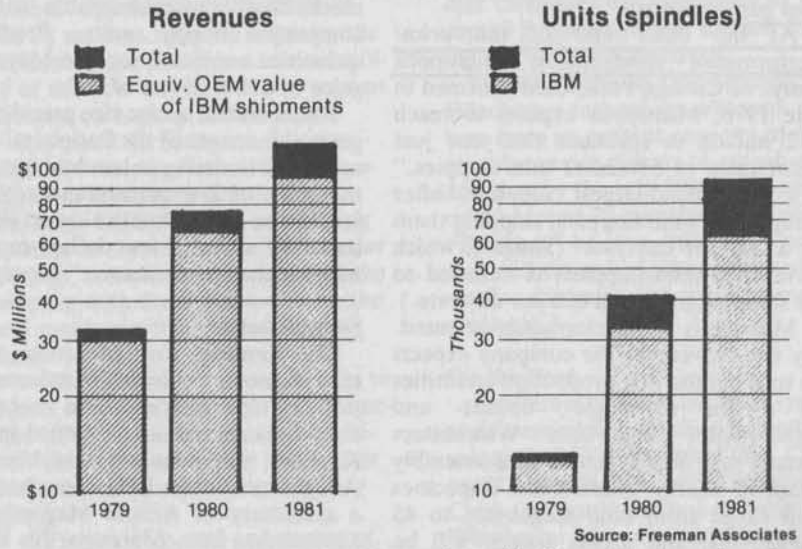
Other estimates vary, depending on how fast Winchester technology is expected to mature and the impact it will have on other rigid disk technologies, such as low-capacity (under 12 megabytes) drives that utilize removable disk cartridges. Whether small Winchesters will impact or complement floppies, which can provide off-line backup for Winchesters, is also an issue. Still, none of the industry observers contacted by ELECTRONIC BUSINESS estimated less than $75 million in annual OEM sales of eight-inch Winchesters by 1982, and estimates ranged as high as $350 million by that year.

High performance, low performance

International Memories, Inc., currently the only OEM supplier of eight-inch Winchesters, has been shipping its Model 7710 dual-platter drive since January. The 7710 has a capacity of 11.3 megabytes (unformatted) and sells for $1900 in 100 quantities. A triple-platter drive that stores 20.5 megabytes will be available later this year for about $2300.

Manufacturers of small Winchesters fall into two camps—those like Shugart Associates that design their products as essentially upgrades from floppies and use floppy type open-loop stepper motors, and those like IMI that use the closed loop track-following servo-positioning techniques of most larger Winchester systems. The latter products, in which reference tracks for positioning the head are prerecorded on one recording surface, are more expensive

The eight-inch Winchester disk market



Source: Freeman Associates

Notwithstanding the many uncertainties associated with the eight-inch Winchester (see box), The Freeman Associates' report, "A preview of the 8-inch Disk Drive Market," predicts a gradual increase in shipments through 1981, by which time "the drives will be truly in volume production with 'Phase Two' products in development." Freeman estimates that there are 12 currently announced, 12 committed and 12 expected eight-inch drive manufacturers, and that there will be about 12 manufacturers of eight-inch media by 1982. ■

"Small Winchester disks have got to be an idea whose time has come."

but provide better performance. Their higher track densities allow more information capacity and, because these systems don't have to count stepper motor increments but can move directly from track to track, faster access speed as well. Closed loop systems also have an inherently greater potential for implementing the new, higher density recording technologies—like thin film heads and plated disks—expected in the early '80s. IMI expects to attain 80-megabyte capacities in its three-platter system by late 1980 even without the use of thin film technology. When available, thin film heads could triple capacity, and plated disks could triple it again.

George Campbell, IMI's director of marketing support, believes it's too early to tell exactly how users will apply small Winchesters or what devices they will most impact. But he suggests that new applications might account for as many small-Winchester sales as present applications do. For example, eight-inch Winchesters will allow small computers to handle multiuser, multiprogramming applications. He points out that currently there are no alternative storage devices that provide the combination of high capacity, fast access and low price required for under-$10,000 multiuser applications. Floppies, while inexpensive, have neither the capacity nor the speed; and cartridge drives, while they might have the capacity and possibly the speed also, are too expensive. Campbell says three of IMI's small-computer OEM customers—Cromemco, Sord Computer and Onyx Systems—are currently developing microcomputer-based multiuser systems.

Campbell believes the reliability of Winchester media compensates for their inability to be removed. "Backup is an issue that's not too well understood," he says, adding that people often confuse protecting with moving and that few applications ever require all the stored data to be removed. Should that be the case, however, tape cartridges can handle the job (ELECTRONIC BUSINESS, September 1979, page 113). Otherwise, floppies make more sense when the data can be logically separated.

Bottom dollar

Shugart Associates, Sunnyvale, Calif., with more than $70 million in revenues last year, is the leading manufacturer of floppy disk drives, having captured more than 60 percent of that market. Its eight-inch Winchester product, the SA1000, has the same outside dimensions and mounting holes as those of its eight-inch floppies and is a scaled-down version of its SA4000 14-inch Winchester. All Shugart disk drives use inexpensive open-loop stepper technology, and all are the lowest cost products of their type.

The SA1000 comes in two versions—the SA1002, a 5-megabyte drive priced at $1140 in 100 quantities; and the SA1004, a 10-megabyte version for $1400. The capacities are low and the access times some 40 percent slower than most of the competition's. But the prices are rock-bottom: In quantities of 1000 and up, the SA1002 sells for less than $1000.

W. Ferrell Sanders, vice president of marketing, explains that Shugart never looks for top performance, preferring instead to go after volume and margin. "We convert high technology products into mass-production products," he says, "and concentrate on the price side of the price/performance ratio."

Every aspect of the design of Shugart's small Winchester reflects attention to manufacturing economies. All the drive electronics are on a single card, and according to product line manager M. Thomas Makmann, the eight-inch Winchesters contain 40 percent fewer parts compared with their floppy counterparts. Shugart's eleven 150-foot-long automated conveyor lines presently turn out floppies at a rate of 2000 per day and 14-inch Winchesters at 30 per day. The company, which since January of last year has been a subsidiary of Xerox Corp., expects to ship 10,000 of its new small Winchesters in calendar 1980.

Top performance

At the other end of the price/performance spectrum is Micropolis Corp. of Canoga Park, Calif. Formed in late 1976, Micropolis expects to reach $12 million in revenues this year just from sales of 5¼-inch "mini-floppies." It's the second-largest supplier, after Shugart, of mini-floppies, shipping them at a 200 per day rate. (Shugart, which developed mini-floppies, is believed to be shipping them at a 600 per day rate.)

Micropolis is performance-oriented. By late November the company expects to turn out the first production quantities of a line of single-, double- and triple-platter eight-inch Winchesters from a new 50,000-square foot assembly plant in nearby Chatsworth. Capacities will range from nine megabytes to 45 megabytes, and access speeds will be more than 30 percent better than the 50-millisecond average of the competition. In OEM quantities of 100, prices will range from $1350 for a single-platter, 9-megabyte drive without controller to $2668 for a three-platter, 45-megabyte version with integral controller/formatter.

Dennis Resnick, marketing manager, says Micropolis aims at cornering the market wherever top performance is required in a box the size of a standard floppy. Micropolis is in particularly hot pursuit of the personal computer market. At a show for personal computer dealers to be held this fall in Philadelphia, the company will introduce a Winchester subsystem designed for the S-100 bus, the so-called "standard hobby computer interface." The subsystem will include Micropolis' version of BASIC and a full disk operating system.

Removable Winchesters?

A wild card in the small-Winchester game is a dual-platter system from Control Data Corp. consisting of both fixed and removable media. CDC won't comment officially on the system, code-named "Lark," but a reliable source within the company says the Lark will consist of a fixed disk and removable 8-megabyte disk cartridge. The system isn't priced yet, but the source estimates an end-user, single- quantity price of "under $2000 for the system and approximately $30 for the cartridge." Pricing is expected in January and first deliveries in mid-1980.

Pertec Computer Corp.'s Peripherals Div. in Chatsworth was one of the half-dozen companies to announce a small Winchester at this year's National Computer Conference in New York. PCC's Model D8000 "Mini-Wini" dual-platter, servo-type drive has a capacity of 20 megabytes and is mechanically interchangeable with the company's floppy units. Production quantities are slated for late March at a price of $1800 in lots of 250.

Ralph Gabai, senior vice president and general manager of the Peripherals Div., says PCC is aiming at low cost but not at the price of low performance. "Others seem to be going after the lowest possible cost. We spend a few dollars more for much higher performance," he says.

Small is better

The Kennedy Co., Monrovia, Calif., manufactures 14-inch Winchesters as well as tape cartridge and reel-to-reel tape backup systems. Founded in 1963, Kennedy was acquired this March by Allegheny Ludlum Industries, becoming a subsidiary of Arnold Magnetics and Electronics, Inc., Morengo, Ill. Kennedy's revenues have grown from $5 million in 1974 to a projected $42 million by year-end 1979.

The Kennedy Series 7000 consists of one-, two- and three-platter eight-inch Winchesters of 4-, 12- and 20-megabyte capacities priced at $1600, $1750 and $1950, respectively, in OEM quantities of 100. The first production units are

Winchesters are high-capacity storage devices that are small, fast, reliable and inexpensive.

slated for first quarter 1980, with evaluation models available in December. The company says customer back orders already account for deliveries of 250 units per month by July.

Russ Bartholomew, vice president of marketing, believes that small Winchesters will have considerable impact on existing 14-inch fixed media. The larger Winchesters will be limited to 100 megabytes and above, he feels, adding that Kennedy's plans include boosting eight-inch capacities to reach that level.

Bartholomew says he feels "very loose and positive" about the small-Winchester market. Kennedy's market researchers predict a slender but rapidly growing market in 1980, eventually leading to the small-computer industry's adoption of the eight-inch Winchester as its standard medium for direct access storage. "In small systems, small is better," he says, pointing out that standard-sized floppies have already demonstrated the ease with which manufacturers of small-business systems can design around eight-inch drives.

John Healion, vice president for computer products marketing at BASF, Inc. in Bedford, Mass., also believes small Winchesters will become the dominant storage peripheral for small-business systems. BASF's 6700 Series will consist of one- and two-platter double-sided drives with 8- and 24-megabyte capacities, respectively. Availability is scheduled for first quarter 1980, with single-unit prices set at $2100 and $3100.

BASF is a major producer of magnetic media and has been working with thin film for several years. Healion warns that IBM might announce a plated disk for use with its S/38 small-business system. "We're watching the S/38 closely," he says, implying that should IBM take that step, BASF would not be far behind.

One of BASF's—and IMI's—customers is Xylogics, Inc. in Burlington, Mass. Xylogics packages the drives with its own interfaces and cartridge tape drives from Data Electronics, Inc. for minicomputers made by Digital Equipment Corp. and Data General. Marketing vice president Harland Lavigne believes that the added reliability of Winchester technology will contribute at least as much to the drives' popularity as their small size does.

"Users will gain confidence in Winchesters as they gain experience," he says. "To justify the cost of a tape cartridge drive, you must have more than just backup applications for it." Xylogics also sells the interfaced Winchesters without the tape cartridge drives.

In addition to the manufacturers mentioned, at least another half-dozen can be expected to announce or deliver mini-Winchesters by early 1980. Memorex, for example, has a two-platter, 11.7-megabyte system, the Model 101, scheduled for first quarter delivery at a price of $1560 in quantities of 100. Priam, a fast-moving company in Cupertino already supplying 14-inch Winchester disk drives, is readying a floppy-sized unit using a linear voice-coil head actuator. And announcements from Century Data and NEC are believed imminent. But regardless of how many players have yet to enter the game, the game has already started.—***A.R. Kaplan***

Winchesters at Mini/Micro

The small Winchester disk drive was by far the most common subject of discussion at the Mini/Micro Conference in Anaheim, Calif., this September. Speakers in at least six of the 24 sessions referred either to the technology, applications or availability of the new drives, and one session focused on backup for them.

Raymond C. Freeman, Jr., president of Freeman Associates, a management consulting firm in Santa Barbara, Calif., and the concluding speaker in the session on Winchester backup, summed up the mood of the meeting with some comments on the still many unsettled issues. Among them:

- The pattern is not yet clear as to which of the "eight-inch" disk diameters will become most popular (outside diameters are either 200 mm or 210 mm, and inside diameters vary also).
- The start-up rate and timing of production volumes are not widely known.
- The degree of sophistication of backup procedures that will be employed is not yet predictable, and consequently the backup techniques that will be selected by user classes are not yet clear.
- The overlap of ¼-inch and ½-inch tape in backup applications has yet to be established.
- The degree to which removable disk cartridges will eventually be accepted is uncertain due to their timing and lack of a standard.

Freeman believes that eight-inch Winchester technology will soon mature from its present capacity of eight megabytes per disk to 14 megabytes, and that by the mid-1980s capacities could exceed 75 megabytes per disk. "By then," he says, "the eight-inch disk will exceed requirements and a smaller diameter disk will become available."

On the floor

Exhibitors of small business systems were also enthusiastic about using small Winchesters. Omni Computer Corp. in San Juan Capistrano, Calif., presently offers a 14-inch Winchester from Century Data Systems, and Omni's president Joe Zedalis plans on adding an eight-incher to the line "as soon as the backup issue is resolved."

Zedalis said an immediate application will be for speech recognition, and the small disk "will help us get into that market sooner than we had anticipated." Omni is considering offering a remote batch transfer service to its users that would allow them to back up their Winchester data on a large disk maintained at Omni's offices.

Hiroshi Okubo, vice president for research and development at Sord U.S.A., Inc. in Kansas City, Mo., demonstrated a multiuser business system with an IMI 7710 Winchester and voice output. "The Winchester gives us a more realistic multiuser system," he said, adding that Sord now targets inventory-oriented prospects such as car repair shops that typically stock 10,000 to 20,000 parts.

But the strongest booster of small Winchesters for micro-based business systems was unquestionably Bob Marsh, executive vice president for Onyx Systems, Inc. of Cupertino, Calif. The Onyx C8000 multiuser system includes both an IMI Winchester and a 3M cartridge tape drive for backup. Marsh says Onyx was formed in December of 1978 specifically to implement eight-inch Winchester technology. "We would not have founded the company if both the disk and the tape cartridge had not been available," he said. ■

COMPUTER SYSTEMS NEWS JANUARY 21, 1980

Study Names Obstacles Blocking Large 8-Inch Winchester Demand

WELLESLEY, MASS. — OEM industry skepticism over non-removable media and resultant "wait-and-see" attitudes are proving to be major hurdles to widespread demand for 8-inch Winchester fixed disk drives—particularly higher-performance models—according to a recent market study.

Venture Development Corp. characterized the demand for the 8-inch Winchester to date as "tepid," noting that the lack of removability, in many instances, is hindering the product's use by systems builders.

Best Chance

The study said the product's best chance for OEM acceptance is in the low-cost, low-performance market segment, with those drives expected to replace floppy disk drives, especially in multiple-floppy systems.

Replacing one of the floppies with a Winchester fixed disk will provide superior performance in terms of capacity, access time and transfer, while allowing the system to retain removable media for archival storage, the study noted.

Shipments of low-performance 8-inch Winchesters will reach 375,000 units in 1984, the study predicted—a figure that would exceed that of all hard disks shipped last year.

OEM purchase prices of the drives will fall to under $1000, it also pointed out.

Stiffest Competition

The 8-inch Winchester's biggest competition is expected to come from future 8-inch cartridge drives, most of which will contain a Winchester-type portion along with a removable cartridge, the study said.

Shipments of high-performance 8-inch Winchesters will reach about 54,000 by 1984, it was noted, while those of 8-inch cartridge drives should be about twice as much.

Larger-capacity drives will continue to compete on a "cost-per-bit" basis during the next five years, while low-cost units will compete on a "cost-per-box" basis, according to the report.

Electronic Business/U.S.

ELECTRONIC BUSINESS/MARCH 1980

Winchester market to surpass early expectations

The rapid acceptance of 8-inch Winchester-technology disk drives by the small computer industry (ELECTRONIC BUSINESS, November 1979, page 89), the availability of "streaming tape" backup storage for them (ELECTRONIC BUSINESS, September 1979, page 113), and the entry of more than a dozen manufacturers of 8-inch Winchesters are among the factors that have forced industry pundit James Porter to revise his earlier estimates of the Winchester market. The author of *Disk/Trend Report*, Porter now projects non-IBM unit sales of Winchesters with 30-megabyte capacity or less to reach 110,000 in 1981 and 145,000 in 1982. Non-IBM unit sales of Winchester drives in the 30- to 200-megabyte range are now pegged at 75,000 in 1981 and 115,000 in 1982. Porter's earlier estimates of the 1981 markets for under- and over-30-megabyte Winchesters were 65,000 and 58,000 units, respectively.

BUSINESS WEEK: April 21, 1980

INFORMATION PROCESSING

The personal computer market, which began only six years ago as one product aimed at hobbyists, has now evolved into a four-tiered market in two separate price categories and is being chased by more than 30 manufacturers offering some 50 different systems, according to International Data Corp., the Waltham (Mass.) market research firm. The two price segments are the low end, selling primarily to the home, hobbyist, and education markets, and the high end, used in the scientific, business, and professional environments. The low end is priced at about $2,500 and is marketed by such companies as Apple, Tandy, Commodore, and Texas Instruments. The high end is marketed by such companies as Hewlett-Packard, IBM, and North Star, and systems are usually priced at about $15,000. Shipments in 1978 totaled 172,000 units, valued at $730 million, according to International Data. It forecasts that shipments in 1983 will zoom to 1.2 million units, worth $3.6 billion.

OEM MARKET TRENDS

'79 Worldwide Floppy Shipments Seen Growing By 97.7 Percent

COMPUTER SYSTEMS NEWS-OCT 22, 19
1979

MOUNTAIN VIEW, CALIF. —Worldwide shipments of floppy disk drives are expected to total 1,448,500 spindles in 1979, a 97.7 percent increase over last year's figures, according to a recently released market report.

James Porter's Disk/Trend Report also shows 1979 will be a record breaker for 5-1/4-inch drive manufacturers, with shipments expected to reach 488,500 units, a 282 percent increase. The report also claims 5-1/4-inch production will reach 2,230,800 units by 1982, exceeding totals for all 8-inch production that year.

Porter feels shipments of dual-sided 5-1/4-inch drives will increase at a higher rate than one-sided production, with two-sided products drawing close to one-sided totals by 1982 as well.

According to Porter, trends in the industry usually occur earliest in the OEM market. This year proved to be no exception as two-sided 8-inch drives began to supersede one-sided shipments. U.S. production of these devices by non-IBM captive makers is expected to peak in 1980 for OEMs, with the rest of the industry following a year later.

Porter estimates production of single- and dual-sided drives to continue at matching paces for 1980 with dual-sided production pulling ahead in 1981. He claims a migration from 8-inch single-sided production to 5-1/4-inch drives for non-IBM word processing products also will contribute to the projected decline in 8-inch single-sided manufacture.

He foresees a peak in non-U.S. production for 8-inch single-sided devices next year. According to Porter, this reflects a concerted effort on the part of Japanese manufacturers to move to two-sided products on a priority basis.

IBM's decline is seen continuing at a slow pace. Apparently, IBM has no further plans to use these drives on new small business systems or key-to-diskette products, but other applications will take up the slack temporarily, the study notes.

Porter feels a decline in average OEM prices for these products is inevitable. Learning curve improvements in production cost will continue to be derived from other floppy drive configurations, all experiencing rapid growth in the future.

He sees the average 8-inch single-sided OEM price reaching $306 in 1980, with a projected 8 percent decrease with each doubling of total shipments. Porter feels all OEM market positions will remain stable, with Shugart Associates in the lead.

The 1980 forecast for 8-inch dual-sided products is for rapid growth. Porter estimates production at 424,300 units, an increase of over 79 percent. He adds that had the industry not experienced severe start-up problems, the total would be higher.

The forecast for 1980 shows the remnants of these problems will still be troublesome in the form of head shortages and introduction of new design configurations, but the 1981 prediction is for smoother production.

The immediate future shows small business and other applications turning strongly toward 8-inch dual-sided products, with projected OEM shipments reaching 601,300 units in 1982, 56 percent of total shipments.

Porter advises this projection represents the market total after allowance for sharing part of key applications with 5-1/4-inch dual-sided drives and 8-inch fixed rigid disk drives.

According to Porter, the U.S. manufacturer best positioned to take advantage of the increased demand is Shugart, whom Porter believes will emerge as the largest producer in this group.

This group also has increased significantly in price since earlier this year, and the standard 25 percent price differential between single- and dual-sided drives should increase, according to Porter. He feels Shugart's recent price increase will keep prices realistic in relation to production costs.

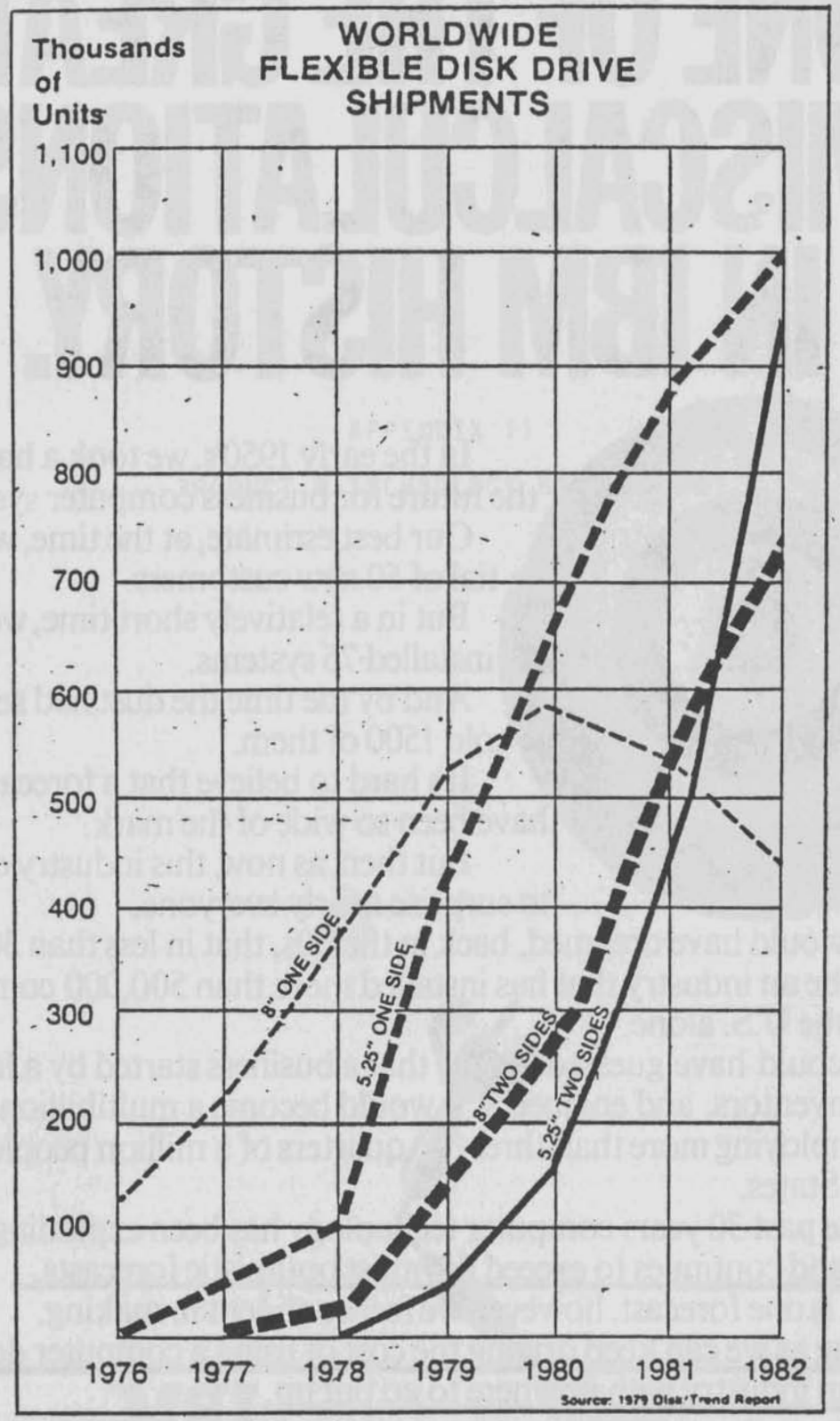
Porter claims the emergence of new captive manufacturing programs will be the rule for the 5-1/4-inch single-sided market. He bases this claim on the sharp growth of 5-1/4-inch drive purchases by individual system OEMs.

Porter feels despite this year's substantial growth, increases will be slighty smaller in 1980, totaling 67 percent and bringing production to 725,500 units. Among the factors dampening enthusiasm in this sector are the impact of dual-sided floppy drives and an expected decline in the hobby and personal computer markets due to the recession.

The forecast for OEM production is for a sharp drop-off in 1982 because of the impact of captive production programs and inroads by dual-sided 5-1/4-inch drives. Porter projects the 1982 OEM total to be 1,006,000—83.5 percent of the total—down from this year's anticipated 98.5 percent of total production.

One factor cited in the OEM market increase this year is price, with costs falling due to a combination of speedy growth and large system OEM purchases of only drive mechanisms. An anticipated introduction by Shugart of a low-cost 5-1/4-inch single-sided drive aimed at the hobby and personal computer market has acted to keep overall costs down, it was noted. Porter's predicted OEM price is $157 for 1980, dropping an additional 15 percent by 1982.

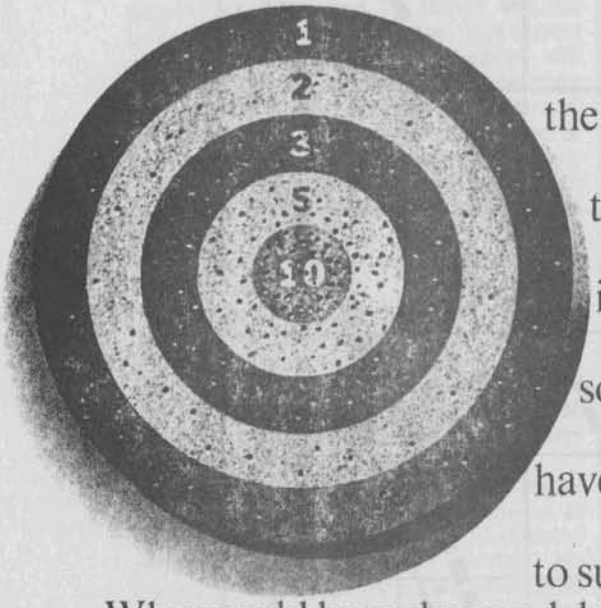
Porter sees 5-1/4-inch single-sided



drives in great demand by very small business applications and word processing applications where capacity needs are too great for single-sided devices and space is a problem. This claim is supported by Porter's forecast for 73.3 percent of all dual-sided production to be directed at these applications by 1982.

As mentioned earlier, this group is expected to experience rapid growth in the next two to three years. Despite the increase in average price, compared with one-sided products, OEM prices are still lower than those for single-sided 8-inch drives, standing at a total of 80 percent of 8-inch price, with that percentage expected to show a further 5 percent decline within two years.

ONE OF THE GREAT MISCALCULATIONS IN IBM HISTORY.



In the early 1950's, we took a hard look at the future for business computer systems.

Our best estimate, at the time, was a potential of 50 new customers.

But in a relatively short time, we'd built and installed 75 systems.

And by the time the dust had settled, we'd sold 1500 of them.

It's hard to believe that a forecast could have been so wide of the mark.

But then, as now, this industry continues to surprise nearly everyone.

Who would have dreamed, back in the '50s, that in less than 30 years this would be an industry that has installed more than 500,000 computer systems in the U.S. alone.

Who could have guessed that a business started by a few dozen scientists, inventors, and engineers would become a multibillion dollar industry employing more than three-quarters of a million people here in the United States.

For the past 30 years computer technology has been exploding, and even today demand continues to exceed the most optimistic forecasts.

There is one forecast, however, we feel confident in making.

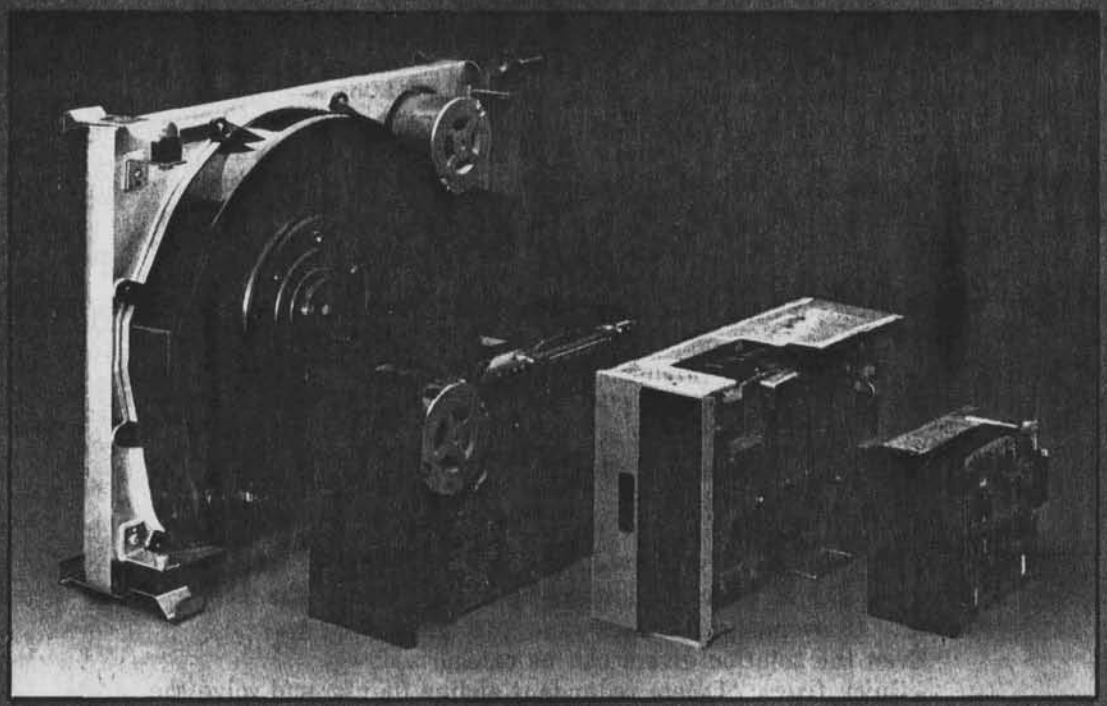
As long as we can keep driving the cost of using a computer down, this looks like an industry with nowhere to go but up.

IBM®

APPENDIX II

PRODUCT & TECHNOLOGY BACKGROUND

Micro/mini storage peripherals driven by disk, tape advances



Courtesy of Shugart Associates

The future of micro and minicomputer storage peripherals looks three-pronged: Winchester technology, streaming tape drives and advanced double-density floppy techniques all promise to become key factors. Indeed, 8-in. Winchester disk drives and streaming tapes should find themselves working together. The former is emerging as a direct replacement for floppies, while the latter is expected to reduce the problems not only of Winchester backup but also of saving and restoring the information recorded on Winchester-based rigid disks.

Double-density floppy recordings, currently considered a major stumbing block for systems designers, will benefit from several new strategies to overcome reliability problems.

Meanwhile, the microprocessor is also making quite an impression on peripherals. Enhancing data management, performing diagnostics and in general "smartening up" the peripheral add up to a major impact on peripheral design.

Winchester technology is the major thrust behind improvements in disk-subsystem designs. Introduced by IBM (Armonk, NY), the technology, which includes 8-in., 14-in. and high-performance drives for large systems, will pave the way for even lower-cost storage and greater reliability.

Magnetic-disk storage subsystems based on Winchester technology must provide for all functions between the CPU and the main memory and the disk subsystems. As a result, a total storage subsystem includes Winchester head-media technology, backup storage, and interface and control of data to the disk, to the backup and to the CPU. For this reason, selecting a Winchester drive actually involves a number of choices for systems designers, including:

- Backup device. Main issue: transfer rate.
- Positioner and track-following systems.
- Drive control. Main question: Should the intelli-

Len Yencharis
Peripherals Editor

gence be drive-resident, with microprocessor control of imbedded disk and formatting?

▪ Interface. Main choices: multiple-spindle, master-slave, intelligent.

Drive reliability is not a major concern, because Winchester technology provides aerodynamically stable head sliders, low head-loading force and sealed drive housings. These features unburden the system designer who is responsible for capturing and retaining data files.

However, backup is a big concern, for the need is three-sided: for system-crash fault recovery, for data-base loading and for archival storage of information.

In small systems, like the stand-alone or communications terminals, downtime is costly. Local, removable storage media are required. In addition to hardware faults, system-crash failures can also occur in software, application programs and operating procedures. And in data-base applications, local backup is mandatory, since the time to provide backup from a central CPU is too expensive.

Typically, the information requiring backup in a disk file of a single-user, single-tasking system is the random-access-file storage, which generally accounts for 20 to 60% of the disk storage. All told, such a system requires a 10-Mbyte magnetic-disk subsystem to store data and load the operating subsystem—1 Mbyte for loading the operating system, assembler and applications programs, 0.5 Mbytes for scratchpad memory and 8.5 Mbytes for data.

A Winchester disk drive with a 10-Mbyte storage capacity can be backed up effectively with floppy disks. Shugart Associates' (Sunnyvale, CA) 8-in. SA1000 is a prime example of designing a Winchester drive with a backup solution.

Here, the major concern is transfer rate between Winchester and backup. Since Winchester drives record information at a higher rate than floppies, a solution would be to design a common controller that integrates the features of the floppy and rigid-disk drive. Shugart's approach is to maximize the similarities between the two drives, like software mapping, track capacities and I/O interface. Data separation with differential line drivers in the data line are used in the driver/receiver circuit to compensate for speed variations.

However, with the high access speed and data transfer of the SA1000, the host computer will not be able to take the data at the drive's rate of delivery. And during the transfer of data between a high-speed Winchester and a floppy, a buffer may be needed to maintain system throughput.

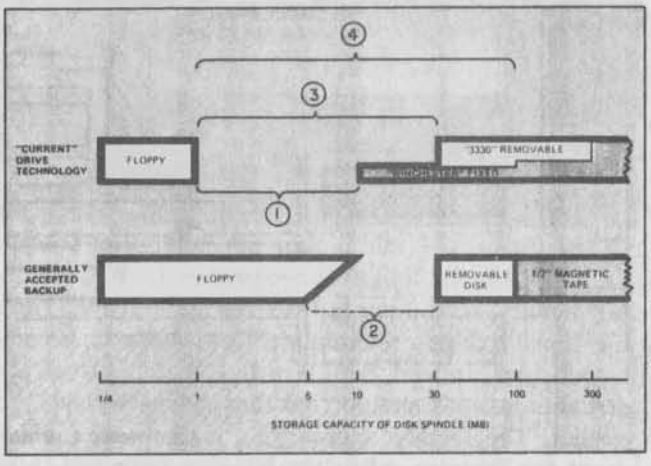
To help system throughput, Shugart recommends sector buffering and interleaving. First, however, the system designer must determine the relative transfer rate between the two disk drives, then the best interleaving scheme. Once the best interleave scheme is determined, the data exchanged between the two drives can be transferred and read as the appropriate logic sectors pass the drive's heads.

One of the first users of 8-in. Winchester disks, Onyx Computers (Cupertino, CA), combines a Z80 microprocessor and a disk tape subsystem that can be backed-up in less than 20 minutes. The system's 8-in. rigid disk, from IMI (Cupertino, CA), is directly attached to DMA-driven parallel and serial interface chips. What's more, the controllers can be programmed to accommodate more than one device (more on μP control later).

Besides the disks, Winchester technology embraces the drive elements that control the rotation of the disk, the positioning of the heads and the servo loop for individual file access. Two approaches are being used for the spindle drives. An ac motor with belt and pulley assembly is low in cost and requires no control circuitry. But it requires a brake and cannot be depended on for writing data during power outages. The other approach is a direct-drive brushless dc motor. It offers compact size, writing during power outages, and the ability to use dynamic braking. However, the motor is expensive and requires control circuits.

Another factor to consider in Winchester drives is the positioner. A linear voice coil, or positioner, combines the small size of a stepper-band positioner with the higher track density of the linear voice-coil mechanism. A stepper-band positioner, on the other hand, offers fast track-to-track access, low cost and small drive size.

The track-following system is also subject to choices. A closed-loop control scheme makes 100% of



Courtesy of Freeman Reports

OEM rigid-disk-drive product gaps are classified as new product gap (1), backup gap (2), effective product gap—either no new product or no backup (3), and Winchester gap—either no product or no backup (4).

the track software usable for data. An open-loop system offers higher performance, higher seek-error rate—and higher cost.

However, closed-loop, track-following, servo-controlled voice-coil actuators combined with access times of 50 ms or less produce storage capacity ranging from 5 to 50 Mbytes. What's more, the drives are constructed so that input and output functions can be controlled by a microprocessor, thereby providing an intelligent I/O interface and simplifying handling of even higher-performance drives as they become commercially available.

Microprocessor control

Microprocessors can also be used to perform diagnostics, control spindle speed and make the interface intelligent. Pertec Computer Corp. (Chatsworth, CA) uses a Motorola 6801 to control these functions in the D8000, a Winchester drive that packs 20 Mbytes of storage capacity and eliminates ac power requirements by using all dc voltages. Besides saving the system designer an extra power requirement, the dc voltages and form factor are identical to floppy drives.

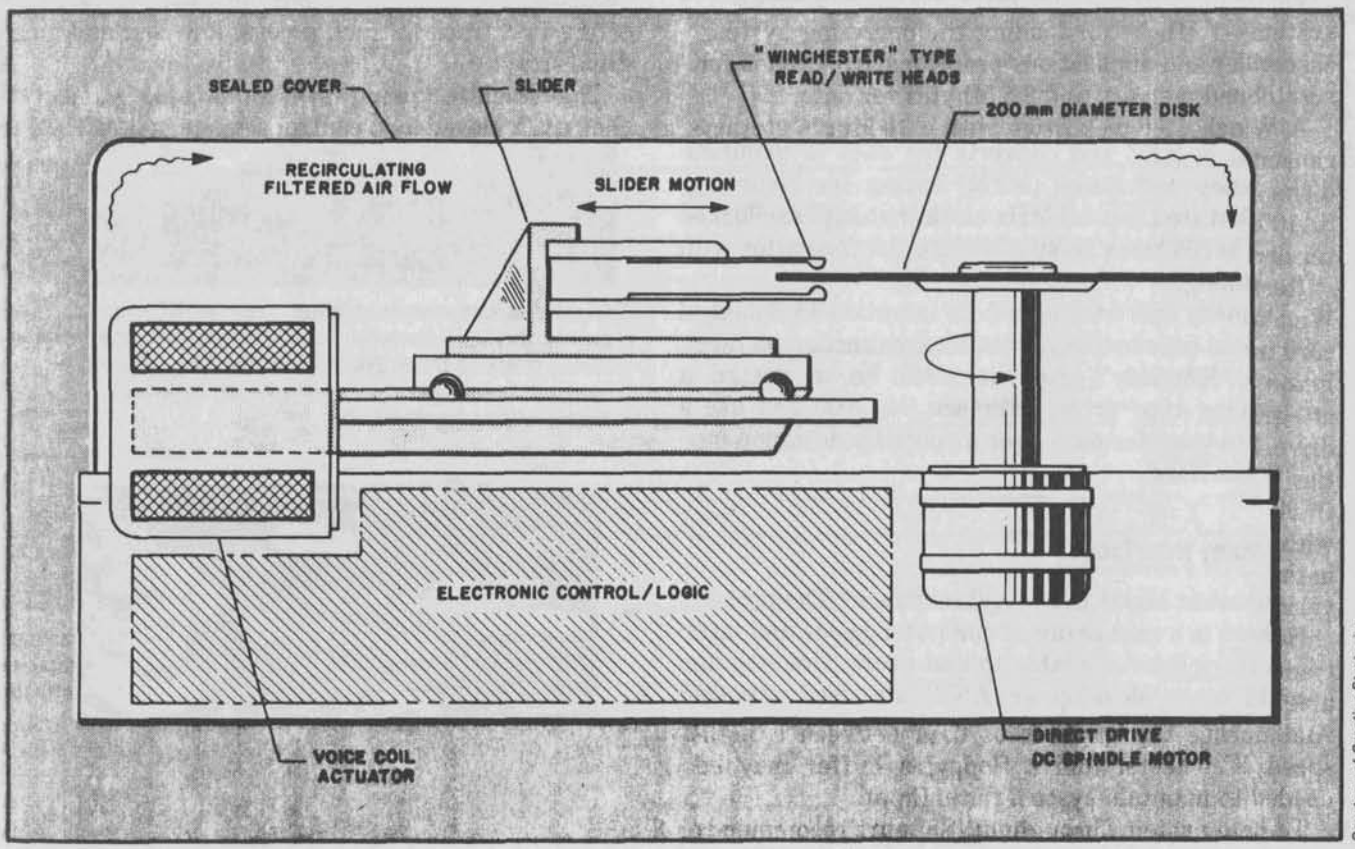
The microprocessor also solves the data-transfer issue. The D8000 interface employs a bidirectional command/status bus and byte-oriented data transfer to simplify the communications between the drive and the host CPU.

The interface is arranged so that as many as four D8000 disk drives can be operated through the interface with a common controller. This is accomplished with a group of disk-drive input lines and a group of output lines, all of which are common to the I/O bus.

Although all lines in the controller cable are run to each disk drive on the bus, eight I/O lines are so addressed that only one drive can transmit or recognize (receive) signals on the bus, thereby obeying handshake and other intelligent protocols. In addition, all interface lines are configured in a negative true-form logic, not the usual positive.

To handle disk-drive malfunctions, the drive may, when selected, request use of the microprocessor bus to transfer status information back to the controller. The format for an 8-bit I/O bus would include: off-track error, illegal command, positioner fault, spindle-speed error, write lockout or illegal cyclinder address.

Another interface that is designed for use with microprocessor-based controllers is the Kennedy Co. (Monrovia, CA) Series 7000 8-in. Winchester. An 8-bit bidirectional bus transfers address information to the drive and sends status information to the control-



Courtesy of Creative Strategies

A Winchester-drive floppy-sized mechanism for an 8-in. disk can easily hold 5 to 10 Mbytes of data. Physical dimensions are identical to that of an 8-in. floppy.

Small-system disk/backup comparison

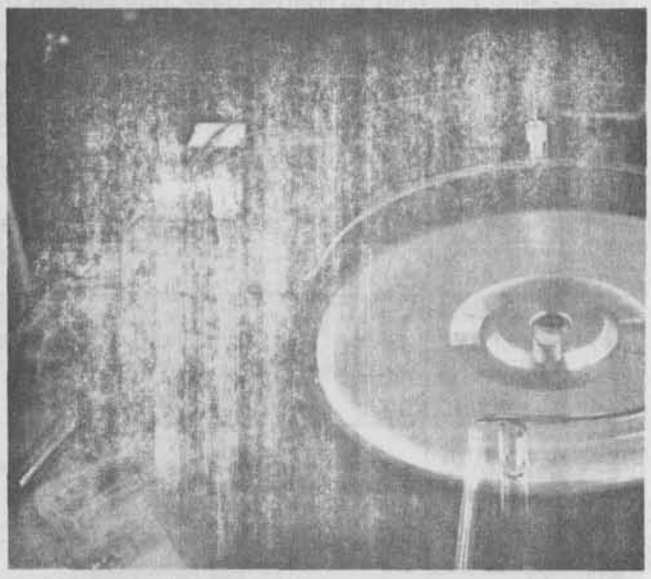
Storage requirements (Mbytes)	Mass storage media	OEM-disk price range	Backup	OEM backup price range
0.5 to 1	Floppy	$500 to $800	Floppy	$500 to $800
10 to 20	8-in. single disk	$1000 to $3000	Cartridge	$600 to $2000
20 to 50	8-in. multidisk or 14-in. single disk	$1500 to $4500	Streaming tape	$1700 to $2500
50 to 300	14-in. or removable disk	$2500 to $10,000	Streaming tape or standard tape	$1700 to $2500 $2000 to $6000

Courtesy of Kennedy Co.

ler. Similar to the Pertec and Shugart units, the Series 7000 uses line transceivers to enable daisy-chain connection of other disks to the bus. However, the 4, 12 and 20-Mbyte drives also feature an optional miniaturized disk formatter, which can be mounted on the drive. The formatter controls seek-and-head selection and sector location, and performs formatted and unformatted read and write operations. Other functions include burst-error correction, staggered sectoring and sector-level write protection.

The Series 7000 also includes drive-control and interface circuits for seeking, writing, reading and fault detection. The drive electronics receives data written in NRZ and converts the data to modified-frequency-modulation (MFM) coding for recording. Also featured is a 5.5-MHz clock that is phase-locked to the servo track to synchronize the formatter with disk timing.

Kennedy has announced its intention to design a universal tape-to-disk formatter (see section on tape). Again, Kennedy's approach will be to design a streaming tape drive, interface the 7000 and use a DMA to transfer data over a specially designed bus-type interface.

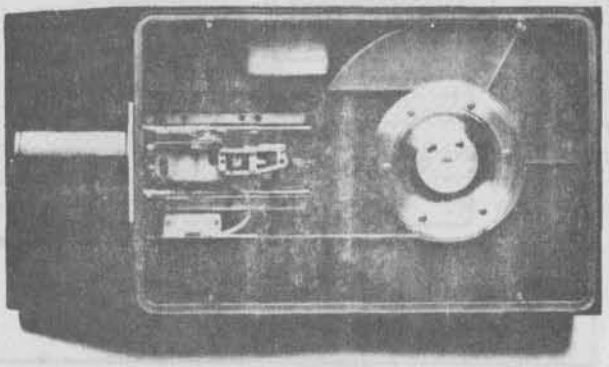


A microprocessor-controlled read/write head-seek actuator in the Data General 6102 Winchester disk drive completes track-to-track seek in 15 ms. The μP executes a velocity-determination algorithm to optimize positioner acceleration/deceleration.

Too many interfaces?

But what about the actual interface? The problem is, there is a vast array of computer buses and interface disciplines available to end users. One solution would be to develop an ANSI standard. Another would be to design an entirely new type of disk controller that can handle the high data rates required by Winchester drives.

Enter New World Computer Co. (Costa Mesa, CA), a relatively unknown company before it announced its 8-in. Winchester at this year's National Computer Conference. The company has also developed a high-speed micro-machine, which not only is adaptable to many buses but also can be microprogrammed to implement many command structures.



An integral microprocessor-based controller in BASF's 6170 series of 220-mm Winchester drives allows interfacing to a disk bus, to storage-module drives or to a host bus.

New World Computer plans to build an Intel-iSBC-compatible memory board and back it up with its 8-in. disk. The complete system looks to the programmer like a 1-Mbyte memory. The configured MegaByte memory system will have cache memory organized as 256 pages of 128 words each. And a memory-transfer request from any master controller on a Multibus will initiate a memory cycle in the RAM controller.

The micro-machine handles requests from pages both in-cache and out. If the requested page is in-cache, a valid code is outputted from the map, which gives the physical address of the requested page. The RAM controller then completes the memory cycle with the physical page address.

As for the micro-machine, it implements a replacement algorithm from the two pages of RAM reserved for its use. A mapping of the pages in-cache back to the hard disk must be stored along with the historical information on all pages currently in cache. Why? Because then an effective decision can be reached on which page to replace in case of a cache miss.

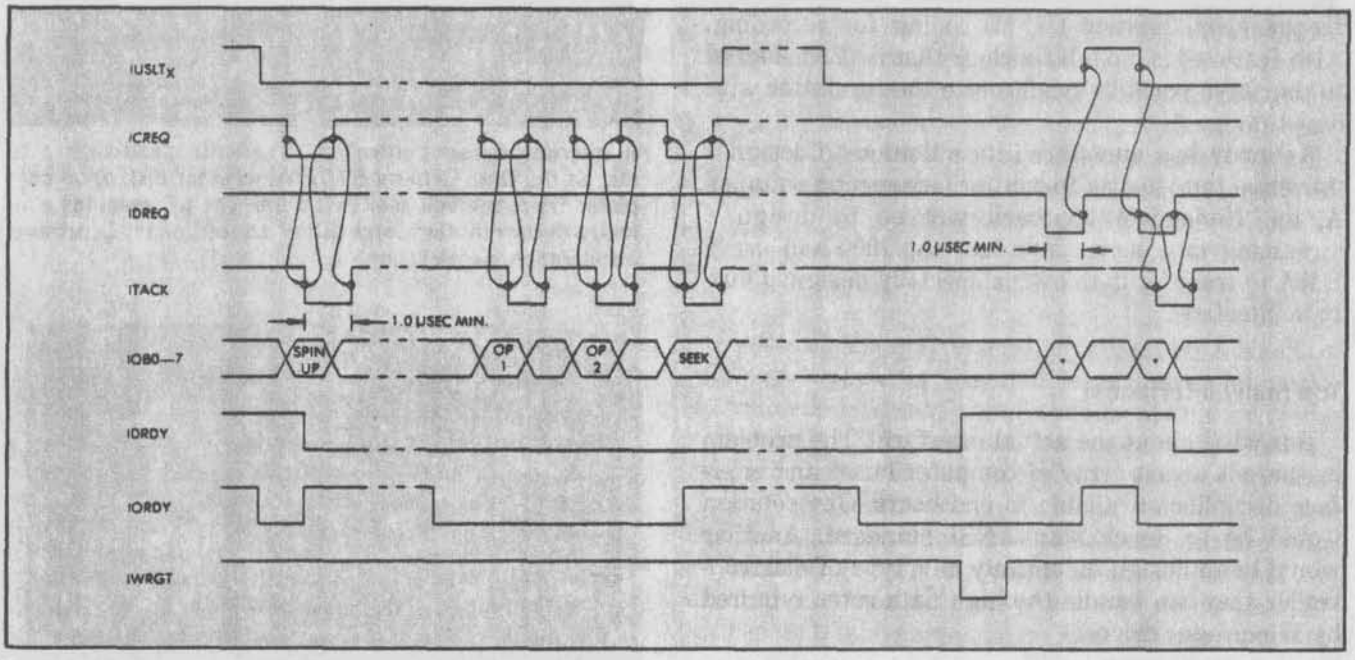
When memory transfer is requested from a page that is not in-cache, the map returns an invalid physical address—e.g., an address reserved for micro-machine use—and the logic inhibits the memory acknowledge to the bus master. Then the micro-machine takes over. Finding from the map tables the page that hasn't been replaced for the longest time, the micro-machine replaces the page from the disk. Then it updates all appropriate map and table entries. The memory is then released and the requested transfer from memory to disk is completed.

Should the system designer decide to go with a different type of interface, the micro-machine needs but a few hardware adjustments.

Another adaptable approach relies on a controller to provide full data-transfer and controller facilities in six standard sectoring arrangements. The Micropolis Corp. (Chatsworth, CA) Model 1220 rigid-disk-drive subsystem has a μP-based controller that does data formatting, decoding, encoding, sector buffering, and error detection and recovery. Consisting of an 8 $\times$ 14-in. PC board and residing in the drive assembly, the controller is attached to a bus-oriented interface and its select capability allows mini or micro systems to be attached via a common interface. Full error checking and error-recovery procedures are automatically performed as well as full buffering for asynchronous operation between host and controller.

What's more, while sectors are normally accessed in logical order, data may be transferred from one sector to a full track on command. Special commands are included to transfer a full track in physical-sector order, thus facilitating loading or dumping from the disk.

In the buffered mode, the buffer can be filled or unloaded at any rate up to disk speed, which is approximately 1 μs/byte. Since transfers are buffered, the host interface need not provide special logic to account for DMA latency for the first data request at each block. In the circuit mode, however, the host



Timing diagrams show that when a drive request is pending, and a unit select is released, the Pertec D8000 interface enables the request to be reasserted automatically whenever that disk drive is again selected.

Small-system disk drives				
Type	Unformatted capacity/drive (M bytes typical)	Average access time (ms)	Average transfer time/byte (μs)	OEM price range
Floppy	0.25 to 1	400 to 500	15 to 30	$500 to $800
8-in. Winchester	4 to 50	25 to 50	1 to 2	$1000 to $3000
14-in. Winchester	10 to 100	30 to 40	0.5 to 1.5	$1500 to $4500

Courtesy of Kennedy Co.

interface must provide for response to all data requests at disk speed.

Another Winchester drive has an integral microprocessor-based controller. But this one provides all format and control operations necessary to interface a host processor and directly control the servo and read/write functions. The BASF Systems (Bedford, MA) 6170 Winchester drive has a controller that combines features of both horizontal and vertical machine architectures. Microinstructions are either 16 or 32 bits wide. The 16-bit instructions make use of secondary decoding to generate more than 50 control fields.

An optional interface, the IEEE-488 bus, can be placed between the host computer and the controller. Command operations passed from the host to the controller via a secondary command group allow 32 remote device-dependent commands to be defined. Whenever a GPIB or IEEE-488 interface is not desired, a standard byte-oriented 16-signal-line bus employing an asynchronous handshake protocol is available for data transfers.

Not only is interface circuitry carried on a single board, but the 6170 can be interchanged with standard floppy drives. So, for that matter, can Shugart's SA1000, Pertec's D8000 and the Memorex Corp. (Santa Clara, CA) 101, which has the largest built-in file of any announced Winchester drive.

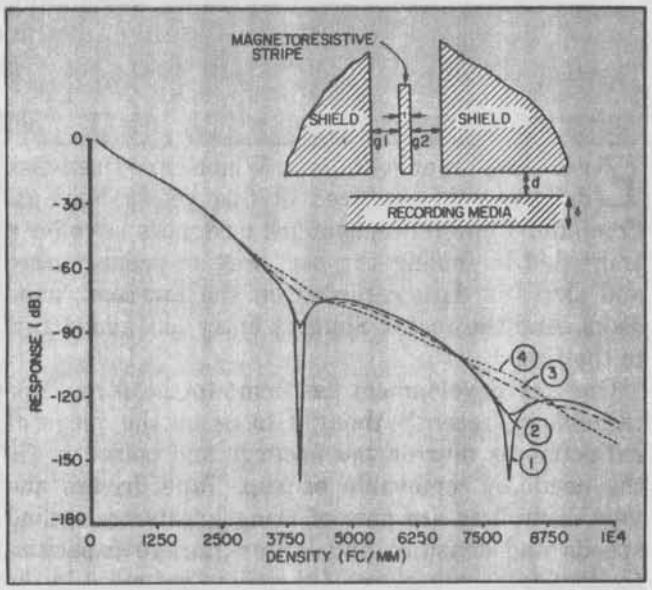
Sealed for the field

Besides the ability to replace floppies directly, another important asset of many available 8-in. Winchesters is their environmentally sealed chamber. A sealed-module approach, like that of the NEC Information Systems (Lexington, MA) D1200, includes a rotary positioner using a voice coil that produces fast and accurate positionings of the magnetic heads. The sealed module can be easily and quickly replaced by the service engineer, allowing the user to add more storage capacity without changing his system's dimensions or structure.

Another advance in the D1200 is a read/write head that carries an LSI preamplifier on its arm. The LSI chip is mounted near the head coil to amplify small signals from the disk surface. The position of the coil reduces failures caused by the amplification of residual electrical noise in the pickup system. Not only that, the drive has optional fixed heads that require no seek time.

On the other hand, the seek stroke in the 6102 14-in. Winchester from Data General Corp. (Westboro, MA) effectively cuts down the stroke to half the disk area and is actually shorter than that of the 8-in. And with the 6102 read/write-head positioning mechanism controlled by a Data General microprocessor, seek efficiency is optimum. The μP executes a velocity algorithm to control positioner acceleration/deceleration.

Besides performing diagnostics, microprocessor control helps with capacity increases. When a capacity increase is needed for the Diskos 3350 and 2050 Winchester drives from Priam (Cupertino, CA), programming accommodates the increase in both tracks and heads.



A shielded magnetostrictive read head researched at IBM makes it possible to record and reproduce data densities up to 5600 flux changes/mm. The calculated density response for 1,2, 3, and 4 are obtained with a flying height of 0.33 μm and a recording thickness of 0.7 μm.

Upgrading floppy-based systems

M. THOMAS MAKMANN, Shugart Associates

Industry seen gravitating to hybrid combinations of floppy disk and Winchester drives to boost storage capacity and performance

Manufacturers of 8-in. Winchester disk drives have brought a new level of flexibility and performance to low-cost computer systems. Before the advent of the small Winchester drive, system designers had limited alternatives when faced with the ever-present requirement for increased storage capacity and better performance : They could interface more floppy disk drives or graduate to larger hard disk drives. The first alternative adds capacity but doesn't enhance throughput and access time. The second usually involves significant system reconfiguration to accommodate more capacity than may be necessary. Most of these large drives—with the possible exception of a few of the more cost-effective 14-in. Winchester offerings—would greatly increase total system cost.

The lower-cost 8-in. Winchester disk drives have opened a new avenue for system designers by providing increased capacity and improved performance over floppy disk drives in a compact, floppy disk-sized package. For example, Shugart's SA1000 is available in 5.3M-byte and 10.6M-byte versions versus a capacity of 1.6M bytes for the double-sided, double-density SA850 floppy disk drive. In addition, Winchester technology-based disk drives are highly reliable, mainly because of their hermetically-sealed recording medium and head, which are free from contamination and interchange problems. Contamination is a major cause of head crashes in removable disk drives.

But Winchester drives do not offer one of the leading benefits of the floppy disk: a low-cost removable medium that is easy to handle, file and mail. Winchester units cannot be considered a replacement for floppy disk drives that are used for data interchange and input/output. For systems with multiple floppy disk drives however, in which one or more of the drives is being used for the main system memory, a Winchester disk drive is an appropriate substitute. For these reasons, the industry will gravitate toward hybrid systems that combine Winchester and floppy disk drives.

As the need for greater storage capacity and performance increases, the designer must determine how to upgrade the system. Will additional floppy disk drives meet the requirements, or should a Winchester drive be employed? Winchester drives using 14-in. disks will not be discussed in this article. However, if

	DOUBLE-SIDED DOUBLE-DENSITY FLOPPY DISK DRIVE	EIGHT-INCH WINCHESTER FIXED DISK DRIVE
UNIT	$500	$1200
CONTROLLER/ OPERATING SOFTWARE	$200	$400
BACKUP/INPUT/ OUTPUT	$500	$500
CABINETRY	$150	$150
POWER SUPPLY	$75	$150

**All prices are approximate*

Fig. 1: Cost comparison *between floppy and Winchester drives by system breakdown.*

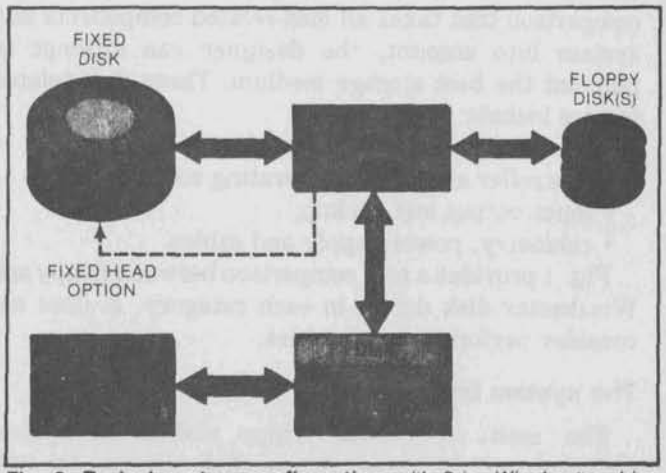


Fig. 2: Typical system configuration *with 8-in. Winchester drive backed by floppies.*

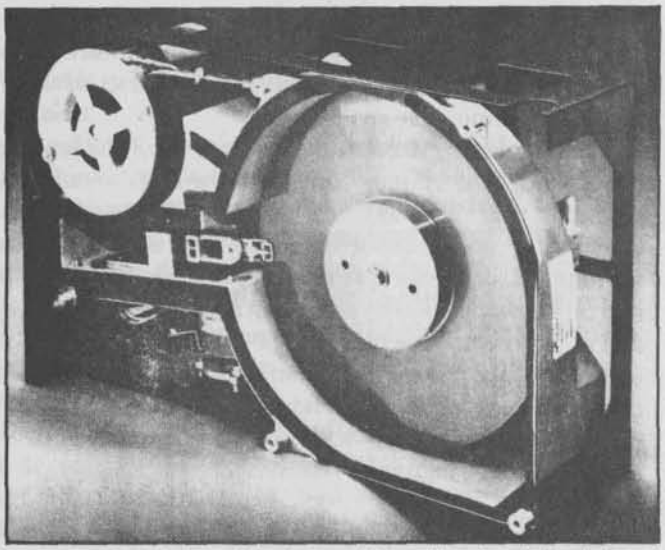
Adding more floppies to the system may be the answer where cost outweighs improved performance.

the requirement is for more than 15M to 30M bytes, and system size is not a major concern, a 14-in. drive should not be ruled out.

Beyond all the other criteria a system designer must analyze to upgrade his system is the ultimate consideration of cost. Because disk-drive expenditures will weigh heavily on the total system cost, the designer should determine whether integrating an 8-in. Winchester drive into the system is more cost-effective than increasing the number of floppy disk drives.

Comparing cost: is a Winchester worth it?

The justification for substituting a Winchester for a floppy disk, particularly in systems with multiple floppy drives, is to get greatly improved performance



Shugart SA1000 8-in. *Winchester drive with printed-circuit board removed.*

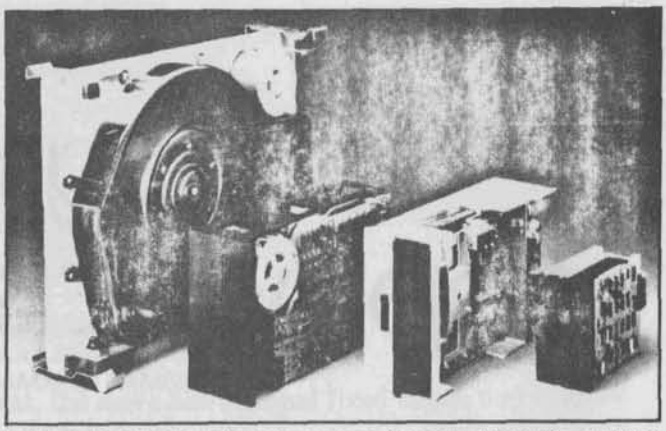
and lower cost. Improved performance comes in the Winchester's much faster access time, greater capacity and increased system throughput. Through a cost comparison that takes all disk-related components of a system into account, the designer can attempt to pinpoint the best storage medium. These disk-related factors include:

- the mass storage device itself;
- controller and system operating software;
- input/output and backup;
- cabinetry, power supply and cables.

Fig. 1 provides a cost comparison between floppy and Winchester disk drives in each category. It does not consider performance variables.

The system breakdown

The unit. A typical floppy disk-based system contains one to three floppy disk drives. In OEM quantities, each unit would cost approximately $350 for



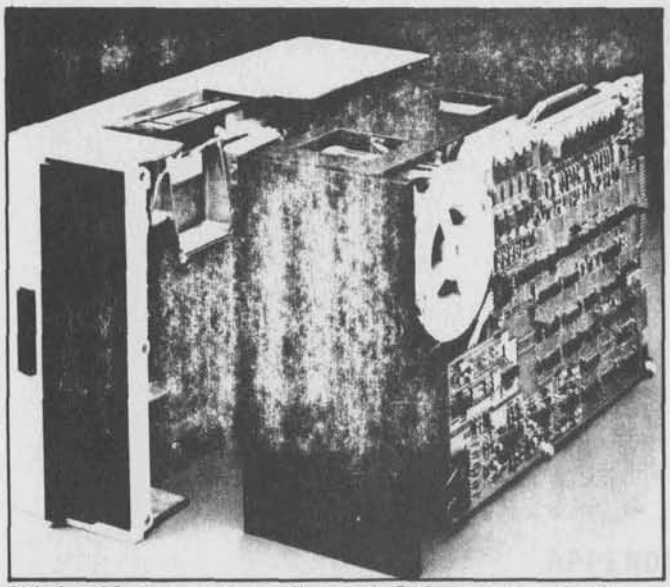
System designer's alternatives *from Shugart. From left: SA4000 14-in. Winchester drive, SA1000 8-in. Winchester, SA851 double-sided floppy and SA400 Minifloppy.*

800K bytes, or $500 for 1.6M bytes (double-sided, double-density floppy drive). The designer can purchase a 5M-byte to 15M-byte 8-in. Winchester disk drive and gain improved performance for less than $1500. Adding floppy drives will increase capacity, but throughput and access time will remain the same; the need for better performance, then, must be appropriately weighted.

Interface. The next-highest-cost items are the controller and the operating software. Integrated circuits provide much of the controller function for floppy disk drives, allowing additional floppy disks at minimal cost. Today's ICs, however, cannot accommodate the data transfer rate of Winchester drives, which is 10 to 15 times that of a floppy disk drive. Interfacing a Winchester drive into a floppy-based system will involve some design effort.

The similar electronics in Shugart's 8-in. Winchester (SA1000) and in the double-sided, double-density floppy disk drive (SA850) allows the use of a common controller for both drives. The additional cost of designing a common controller to accommodate both the floppy and fixed disk drives, rather than one dedicated solely to the Winchester drive, is negligible. By making the common signals identical for both the SA1000 and SA850, the designer can achieve system economies with a common controller. Further, software developed for the SA850 can be mapped directly onto the SA1000 because they have identical track capacities. Other advantages of integrating a Winchester disk drive include improved controller features, such as error correcting code (ECC), sector interleaving and a sector buffer, all of which add to data integrity and system throughput. These features are used in Shugart's SA1000 controller, which was provided for the SA850 at no added cost to the Winchester controller.

Backup. A leading concern of designers employing Winchester disk drives is backup. The need to back up 8-in. Winchester disk drives is scaled down considerably from the requirements for 14-in. units, which contain 50M to 75M bytes. For 5M- or 10M-byte units, such as the SA1000, the 1.6M-byte capacity of the double-sided, double-density floppy disk drive is a



Side-by-side *comparison of Shugart's SA851 double-sided floppy and SA1000 8-in. fixed disk drive, which have the same physical dimensions and mounting holes.*

suitable backup device. If the floppy disk drive is already in the system, backup for the Winchester drive entails little or no additional cost. Fig. 2 shows a system with an 8-in. Winchester drive backed by floppies. In a purely floppy disk-based system, the floppy disk drives serve as their own backup, and no additional expense is required to answer the backup question.

Cabinetry and power. Cabinet modification is not an issue for a multi-floppy versus Winchester-based system because most 8-in. Winchester drives fit into the same slot that a floppy does. But the Winchester's typically higher power requirement doubles the power supply cost—from about $75 for floppy disk drives to approximately $150 for the fixed/floppy drive configuration. For those few Winchester drives containing AC stepper motors, the power requirement is the same as for floppy drives, but adds nothing to the cost.

It should, then, cost $900 to $1200 to upgrade an existing floppy disk-based system by adding two floppy-disk drives, depending on whether single or dual-headed devices are used. In contrast, it will cost from $1500 to $1800 to upgrade by interfacing one of the lower-cost 8-in. Winchester drives.

Beyond cost: enter applications

Another major consideration, which doesn't directly involve cost but should significantly affect the designer's choice, is the system's intended use. How does an engineer know if and when the current system has outgrown floppy technology and when the move to 8-in. Winchester disk drives should be made? It is impossible to answer arbitrarily that if one system has three floppy disk drives, the designer should switch to fixed disk drives. It is equally impossible to conclude that specific applications, such as personal computing, require only floppy disk drives, while others, such as small-business computing, are suited only to Winchester drives with floppy disks as backup.

But there are two basic questions that should be asked:

- How many concurrent users are there for the system?
- How many functions will the system perform?

If the system is a stand-alone, single-user, single-function unit, 5M bytes of storage is often more than required. Even for a multi-user, single-function system, floppies can handle all the tasks.

When system requirements become more complex, with multiple users sharing the same data base and performing several functions, the need for 5M and 10M bytes becomes more apparent. A typical example—and a candidate for a Winchester—is a combination word-processing/data-processing system with several operators sharing the same data base for a variety of tasks. The Winchester drive would also be particularly suited to a remote computer location that is part of a distributed data processing system. The operator would not have to access the central data base for daily operations. The 8-in. Winchester disk drive makes the most sense for systems that require a significant amount of program and system data storage, high throughput, large-scale data-handling or networking and data-communications capability.

The 8-in. Winchester disk drives have given system designers tools they once lacked: inexpensive storage with minimum system redesign effort. While there will still be a market for floppy-only systems, an 8-in. Winchester disk drive and a floppy disk drive often make a good marriage. ■

M. Thomas Makmann has been product line manager for rigid-disk products at Shugart Associates, Sunnyvale, Calif., for the past two years, after serving for three years as a product sales manager at Memorex Corp.

APPENDIX III

DATA BACKUP ISSUE

BusinessWeek

April 7, 1980

Information processing

PERIPHERALS

Solving the disk backup problem

The small Winchester disk drive promises to become one of the hottest new computer memories, thanks to its speed and low price tag. But the lack of a low-priced memory to back it up is slowing down some small-system makers from switching to the new unit. Now many manufacturers, large and small, are jumping into the market with new designs to handle the backup job.

Cipher's Muller: Aiming for industry leadership with a $2,000 backup unit.

Robert J. Burroughs

The problem is that the so-called Winchester design—recordlike platters magnetically store the data in sealed, contamination-free units—rules out the conventional methods of making duplicate records of the stored data. Other disk drives make the job easy because they have removable disks. In the big computer systems that already use the older, large Winchester drives, data are usually transferred off-line to a tape for safekeeping.

Costly. But such ½-in. tape drives are expensive, costing five times more than the new Winchester models. The 8-in. Winchester appeals to the small-computer maker because he can buy one for his system with 10 million characters of storage for only $1,000 in quantity purchases. "What's the sense of switching to Winchester if there's no cost-effective, reliable, backup technology?" asks Samuel F. Gagliano, director of small business systems at Wang Laboratories Inc.

The reason Gagliano and other small-system makers are anxious to add the 8-in. Winchester to their products is that these fast-proliferating systems are doing more and more jobs in the office and factory, and more local-memory capacity is needed to store the data for these tasks. And the backups are vital to the smallest of systems. If a businessman is running his payroll, for instance, and his Winchester disk drive fails, he cannot afford to hold up paychecks for 48 hours while his system is being repaired. But with a backup copy of these records on disk or tape, he can complete his payroll run on another system. "Backup is like a life insurance policy," says Raymond C. Freeman Jr., an industry consultant.

Such backup is also needed for simply making more efficient use of the disk. If payroll records are used only once a week, the data can be off-loaded and stored until needed. At the end of the year, a company may want to move the financial data off-line to make room on the disk.

For many companies, the lack of a low-priced backup system for the small Winchester disk memories provides a market opportunity. "The fuse on the backup market has been lit, and requirements over the next three years should explode," says John W. McIntosh, director of market planning for Storage Technology Corp., which plans to enter the backup market for the older, large Winchester memories. Consultant Freeman figures that the market for devices to back up Winchester disks will triple to $300 million in 1983 from $100 million in 1979. Low-cost tape drives will account for 61% of that 1983 volume, he says.

In February, Cipher Data Products Inc., a San Diego maker of tape drives, began shipping its Microstreamer, a 48 million-character tape unit selling for $2,000 in quantity. And a next-door neighbor, Data Electronics Inc., has just begun to ship two ¼-in. tape cartridge models—one 10 million-character capacity unit for $514 in large quantities and a 20 million-character unit for $525.

Stripped down. To get the price down, manufacturers have stripped down their conventional tape drives and switched to a technique called "streaming." By designing these units primarily for backup storage, the makers eliminate costly electromechanical components that are used for starting and stopping the tape to search for data. As a result, large blocks of data can be dumped onto the tape from the Winchester disk, then rapidly put back on the disk again.

Both of the San Diego companies expect to get a boost out of the backup market. Data Electronics expects that its two new units will push total sales from $7 million in 1979 to $18 million in 1981. Backup sales will account for 70% of the increase. Cipher's revenues will

rise from $15 million in fiscal 1979 to $50 million in 1982, predicts President Donald M. Muller. The backup products will account for 50% of the increase in sales, he says, adding: "We've got an opportunity to be a leader."

The two small companies will have plenty of competition, however. Kennedy Co. has introduced two new backup tape drives, and Pertec Computer Corp. and Perkin-Elmer Corp. are both working on backup models. Meanwhile, International Business Machines Corp. has been shipping its 8809 backup tape drive since last June.

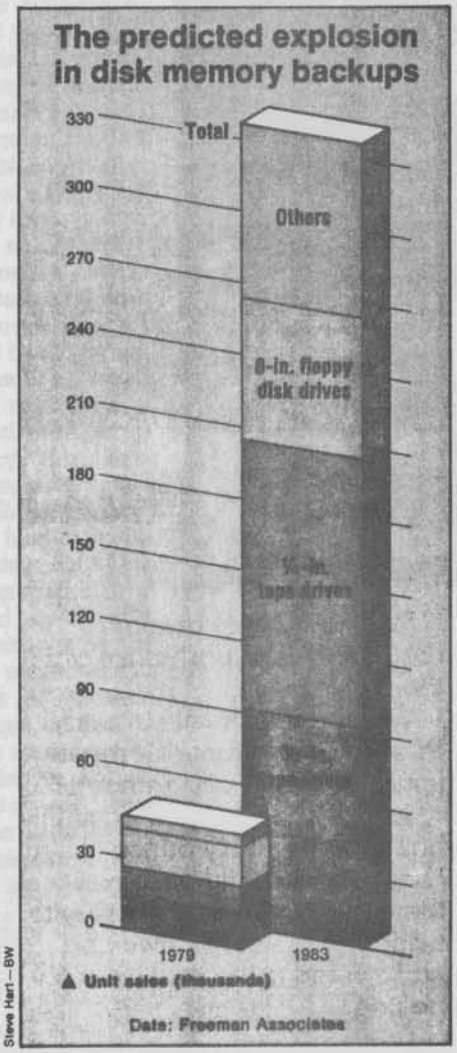
Other answers. The stripped-down tape drives are not the only answer to backing up the Winchester memories. "We're looking at everything in order to give our user a way to solve the problem," says Richard G. Bulgarelli, technology marketing manager for peripheral products at Sperry Corp.'s Univac Div. One possibility that Sperry is evaluating is an 8-in. Winchester and a tape backup packaged as a single unit. Microcomputer Systems Corp., the small Sunnyvale (Calif.) developer of the combination unit, expects to begin shipping it next year priced at less than $5,000 in large quantities.

Control Data Corp. is coming out with a similar memory called Lark, which folds together an 8-in. Winchester disk with a removable one for backup. Such combination products could grab a healthy chunk of users who currently back up a disk memory with another one. "The Lark could take some of the wind out of the backup [tape] market," says David E. Gold, a computer consultant in Saratoga, Calif.

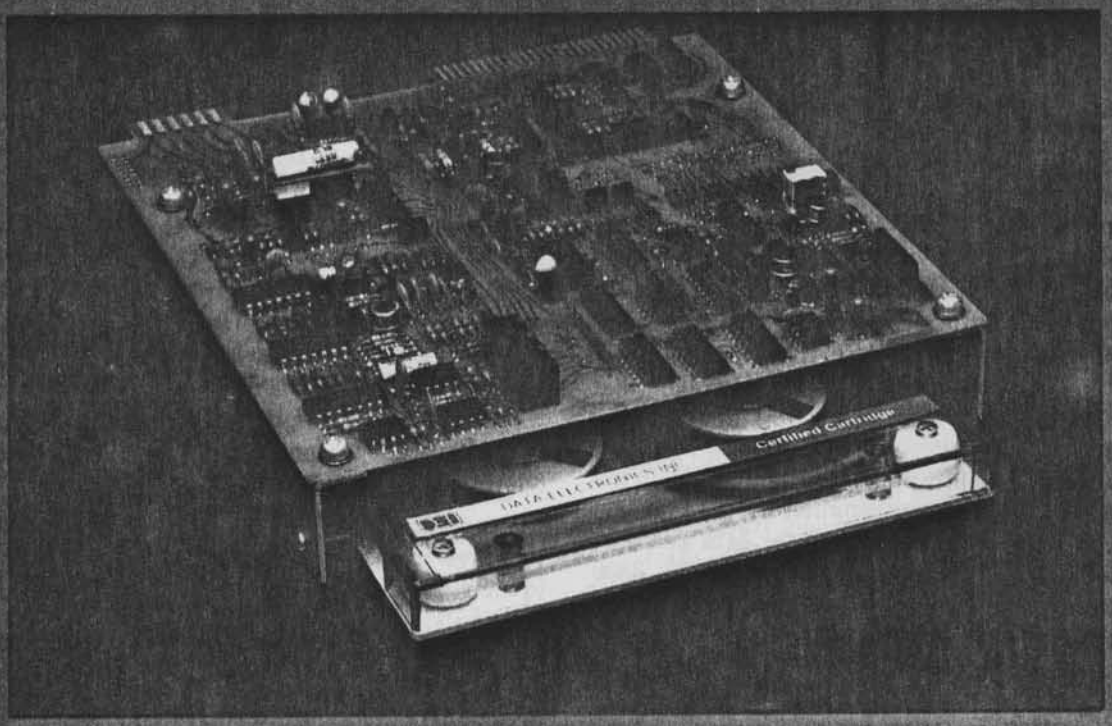
Perhaps the lowest-cost backup for the Winchester is the floppy disk memory, which can cost system makers as little as $400 each. About the only major drawback to the floppy, which uses removable flexible disks the size of a 45-rpm record, is its capacity to store just 1 million characters. That means that a user will have to load and unload the floppy disks when a large chunk of data is being transferred. "Floppies can be an operational nightmare for backup," says Robert F. Marsh, president of Onyx Systems Inc., a San Jose (Calif.) maker of small business computers.

Limited output. The biggest sales barrier to new backup products now is that no company—other than IBM—has demonstrated the ability to turn these products out in high volume. "The backup vendors are all talking, but no one is really making yet," says Wang's Gagliano. So he has decided to use the proven floppy disk drive as a Winchester backup in a new small business system that Wang will introduce this spring.

What Cipher's Muller and its new competitors are counting on is that the market for backup memories will prove large enough to generate significant sales for all the alternative products. "Winchester is just the beginning of the need for backup," says consultant Freeman. "The market is here to stay." ■



Streaming tape improves backup



Courtesy of Data Electronics, Inc

Ever since an array of 8-in. Winchester fixed-disk drives was introduced at this year's National Computer Conference, systems designers have been embroiled in finding the best way to secure, store and ship the data recorded on the low-cost, fixed disks. And the recent Shugart entry has added fuel to the fire.

One key development has come to the fore: Tape technology, recently thought to be on the verge of extinction, is now on the upsurge and poised to fill the need for removable backup. Tape drivers and tape cartridges are now offering greater recording speeds and densities and larger storage capacities for low cost, with more of the same promised in the future. Several advances are spurring them on:

- Continuous—streaming—tape flow
- Microprocessor-controlled tape transports
- More effective recording formats
- LSI-based diagnostics
- Improved heads.

Principally save and restore

Magnetic tape has been reborn with the introduction of the IBM 8809 ½-in. magnetic-tape unit, commonly called the "streaming tape." Where three motors and a vacuum column were needed to monitor the speed and tension of the tape as it passed the read/write heads, the streaming drive transports the tape directly from reel to reel, without capstan or vacuum columns, while tape tension and velocity are controlled electronically. In the 8809, specifically, LSI circuits constantly measure the geometry of the tape from the reel to the head, and electronically adjust the reel to keep proper tape speed and tension.

Designed for use with either an IBM 4331 processor or an IBM 8100 information system, the 8809 operates in two modes: stop-and-start (low speed) or streaming (high speed). Both modes are set by command under program control from the host processor. The stop-and-start mode means 0.318-meter/s operating speed (12.5 in./s), which makes the 8809 suitable for processing and blocking data-base and data-communications information. This mode also provides a data rate of 20 kbytes/s.

For disk backup, however, the streaming mode is eminently suitable: Operating speed is 2.54 m/s (100 in./s), and the data rate is 160 kbytes/s.

Speed isn't the only difference between the two modes. For example, when in the low-speed mode a command is received by the tape subsystem, the tape accelerates and stops within the interblock gap

(IBG). In the streaming mode, however, the tape motion continues without stopping and starting, provided the next command is received during the command reinstruction. Commands arriving afterwards or commands that are discontinued will stop the flow. In addition, when there is a command overrun, the 8809 either automatically recovers and executes a command received during the recovery cycle or it awaits the next command.

The 8809 "owns" a specified block of reserved data in an IBM 4331 processor-storage area. The block contains statistical information that includes error, usage, overrun and retry counters. The counters are updated by a magnetic-tape-unit adapter, which features functional and error-handling microcode. When one of the counters overflows, the overflow-control flag is present for each respective tape unit. The next I/O-start instruction that addresses the tape unit having the active overflow flag causes a unit check to be set in the initial status. The unit-check condition causes the operating system to issue a sense command to the addressed tape unit.

Another special adapter feature is the ability to implement both half-word-programmed I/O operations, and channel-I/O operations to transfer data and control information between a program and the 8809 adapter or tape unit. Two data buffers in the adapter, each containing 251 bytes of temporary storage, are used during channel-I/O data transfers between tape and processor.

For recording, the 8809, as well as other streaming tape drives, uses a phase-encoded (PE) format, which moves data at 1600 bits/in. The PE is more reliable than a nonreturn-to-zero-inverted (NRZI) format because it can run with one bad track of data. A group-recording format (GCR) for streaming tape is still too expensive because the code's two-track error correction can cost as much as $5000 to implement—and require hundreds of ICs.

As for ICs, the major impact on streaming-tape devices has been the microprocessor, acting as a CPU. It determines when to turn on the read/write heads, erase bars, sense EOT/BOT and keep track of recent tape history for diagnostics. Cipher Data Products Inc. (San Diego, CA) uses an 8-bit μP in its F880 microstreamer tape. In the F880, a digital tachometer for measuring how fast the tape passes an optical encoder is constantly monitored by the CPU, which also provides built-in diagnostics for file protection.

A CPU can also be used as an intelligent formatter for transferring information directly from an 8-in. rigid disk. The 6809 streaming-tape drive just announced by Kennedy is designed so that an intelligent formatter can be interfaced to an 8-in. rigid disk. This permits the OEM designer to worry only about designing one controller for the tape/disk combination. In addition, the 6809 features 46 Mbytes of unformatted storage capacity and a 1×10^9 hard error rate.

Kennedy expects to include an industry-compatible formatter interface by December, 1979, and to announce in 1980 an intelligent tape-formatter interface that will include interfaces for 8-in. and 14-in. rigid disks. The bus interface for the formatter will operate asynchronously and use a DMA channel for handshake protocols and data transfer.

Another approach is to embed one μP in a tape formatter. The 9X00F double-density magnetic-tape formater from Kennedy employs a bit-slice CPU and on-board ROM to help with the repair of nine-track read-after-write transports.

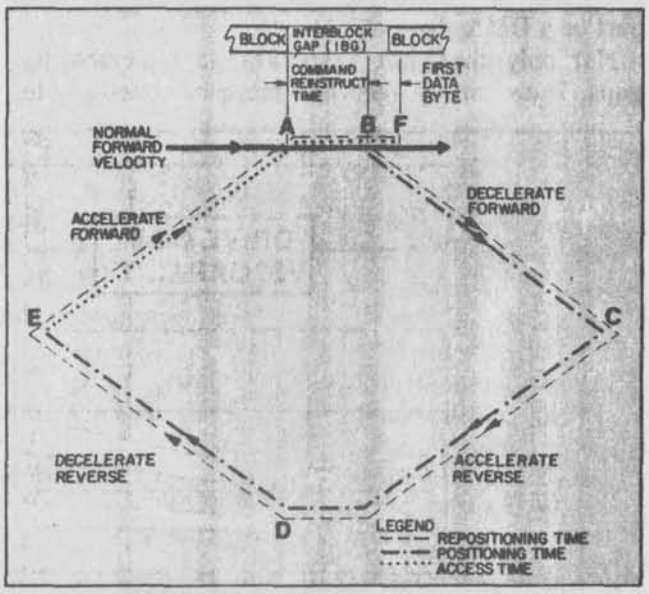
The 9X00F handles up to four daisy-chained transports with two different speeds, while on-board DIP switches control the speed, status and address designation. Provisions can be made for fixed or variable-length erase commands and tape editing. In addition, the CPU controls allow a response to space-forward-or-reverse one file command.

Microprocessor-based magnetic-tape subsystems are also prevalent in many minicomputer structures. A notable example is the TS11 from Digital Equip-

Small system backup transports

Type	Unformatted capacity (Mbytes typical	Average transfer time byte (μs)	OEM price range
Cartridge Streaming ½-in. tape	2 to 35	40 to 200	$600 to $2000
Standard ½-in. tape	10 to 50	6	$1700 to $2500
Standard ½-in. tape (GCR)	5 to 50	5 to 100	$2000 to $6000
	45 to 180	1.28 or 2.13	$10,000 to $15,000 with formatter

Courtesy of Kennedy Co.

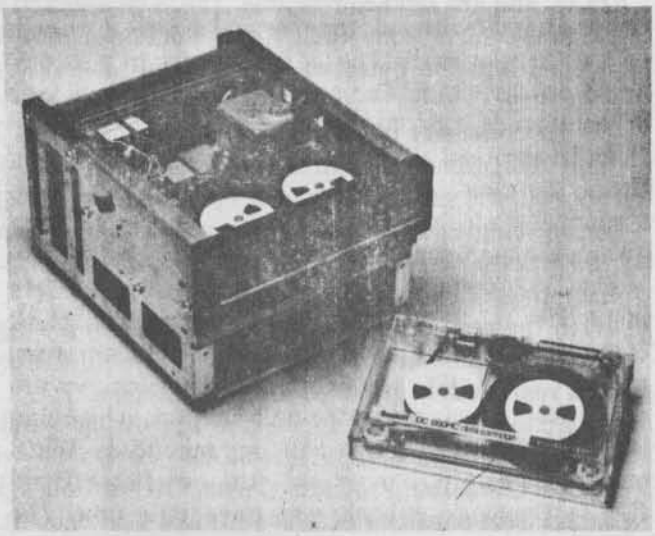


Streaming-mode recovery following a command overrun is automatic in IBM's 8809 streaming-tape drive. If a command overrun is expected,the high-speed streaming mode should not be used.

ment Corp. (Maynard, MA). Primarily designed for PDP-11 Unibus-based minicomputers, the TS11 incorporates a four-chip μP assembly for intelligent operations. Because of the CPU set, several routines can be executed: diagnostics, controlling capstan speed, selecting read/write voltage threshold levels and performing formatting functions. Forty-seven diagnostic routines are held in an on-board ROM.

Data integrity in the TS11 is ensured through automatic phase-encoded, error-correction parity checking along the entire data path and read-after-write verification of input data. What's more, a subset of the diagnostic-routine library is made available to the user.

Some microprocessors, like Intel's 8085A, not only do diagnostics, they also interface 6400-bit/in. tape cartridges to small systems. The intelligent interface allows a streaming tape drive to be software-transparent and allow up to a 32-k recording length.



Packaged the same as a standard floppy, the HCD-75 cartridge drive from 3M offers 75 times the capacity of a 4 × 6 cartridge. The tape head is a single-track device positioned at one of 16 tracks by a high-resolution stepper.

The cartridge connection

Streaming digital cartridges are also expected to back-up 8-in. Winchesters. The cartridges can be interfaced to disk-based computer systems by using the CPU as a tape controller, using a single controller for both disk and tape, or building a dedicated cartridge-tape-drive controller. Many OEM-system designers will be building their own controllers, since their particular minicomputer architecture will require special hardware and software restrictions.

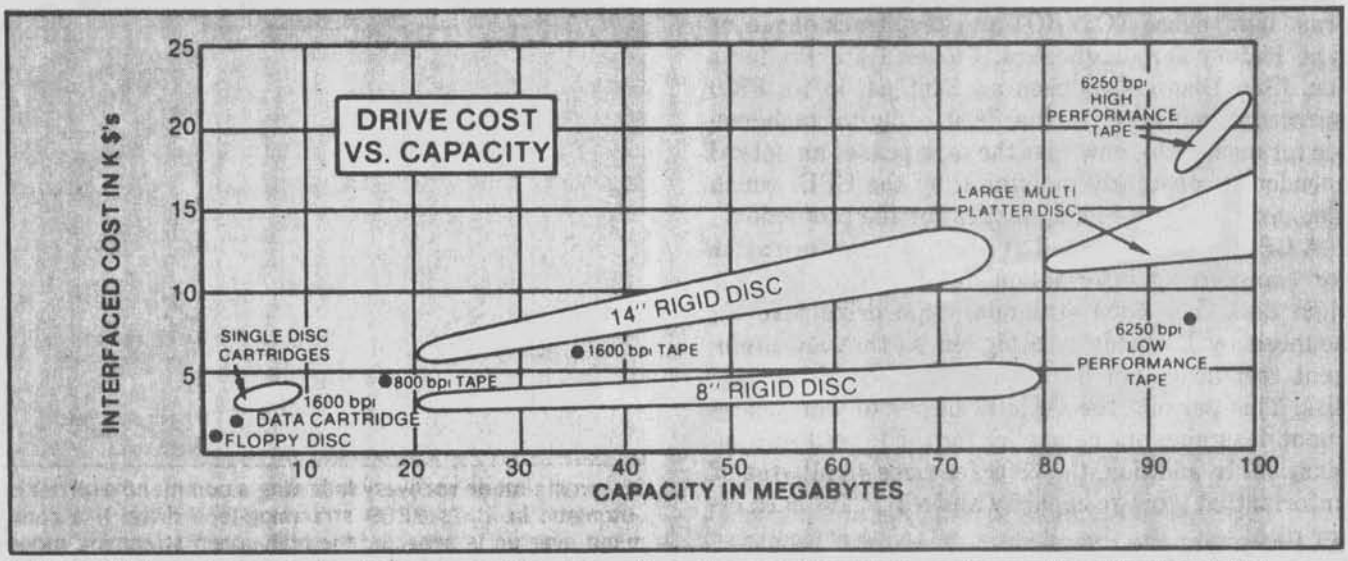
Meanwhile, however, OEM cartridge suppliers are announcing higher-capacity drives. One significant advance, a 75-Mbyte cartridge drive from the 3M Co. (St. Paul, MN), needs only one controller in a multidrive control environment. The HCD-75 I/O structure allows the designer to interface to CPU-based systems via either a host controller, a high-speed I/O port or a DMA channel.

Not only that, but there are no interrecording gaps. Data can be recorded more compactly using space previously allocated to the gaps. For long data recordings, the control system automatically takes on additional blocks.

Data are transferred asynchronously at 16-bit rates with a fully buffered I/O channel. In a burst mode, the system can transfer at a rate up to 4 Mbytes/s. Average data-transfer rate is 20 kbytes/s.

Another streaming cartridge drive records 34 Mbytes of unformatted data on seven tracks. The Data Electronics Inc. (Pasadena, CA) Microtape streamer yields a bit density of 6400 bits/in., or about 4.32×10^6 bytes/track. The recording technique is a proprietary replacement of the MFM coding found on earlier high-density drives. DEI expects to announce a nine-track cartridge in early 1980.

Nonstreaming high-performance tape drives are also swelling their storage capacities and using more recording formats. The 1935/1950 tape subsystems from Storage Technology Corp. (Louisville, CO) offer tri-density drive and a choice of 50, 75 or 125



With 75 Mbytes of storage, the HCD-75 cartridge drive will cost less per Mbyte than corresponding 8-in. rigid drives.

in./s, and are field-convertible. The tape unit and the format-control unit (FCU) are microsequence-controlled and the detection scheme is PLL-read type circuitry.

The tridensity recording format includes NRZ, PE and GCR. Since the three formats run at different speeds, the 1935/1950 must operate like a single-drive, single-formatter configuration. Write-saturation curves are run track-by-track, and metal-film resistors ensure optimum write performance.

In the read mode, read-signal amplitude is adjusted to a nominal level track-by-track. A full differential read path is provided for each channel.

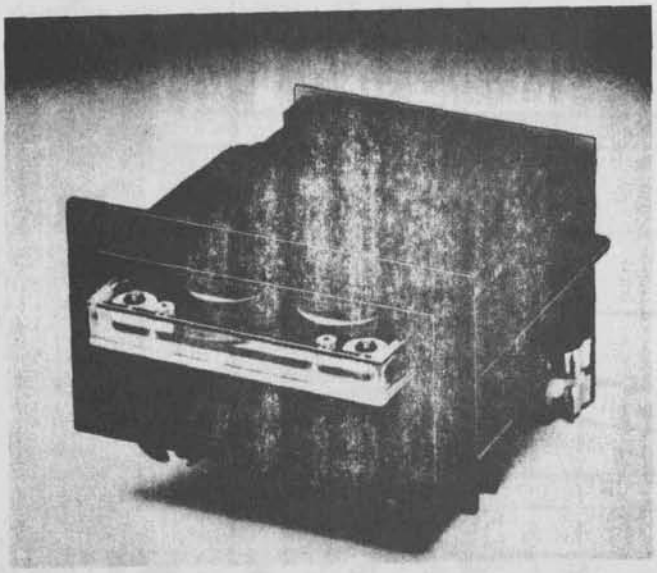
Mixing speeds and formats is a growing trend at high-performance tape levels. The Series 80 from Telex Computer Products (Tulsa, OK) not only provides data densities of 800, 1620 and 6250 bits/in., it also includes data formats for NRZI, PE and GCR, as well as tape-transport speeds up to 125 in./s and data rates to 780 kbytes/s.

Even the GCR format, considered too expensive for many minicomputers, is making inroads. The format offers a data density of 6250 bits/in. as well as sophisticated diagnostics and a high level of communication between peripheral and CPU.

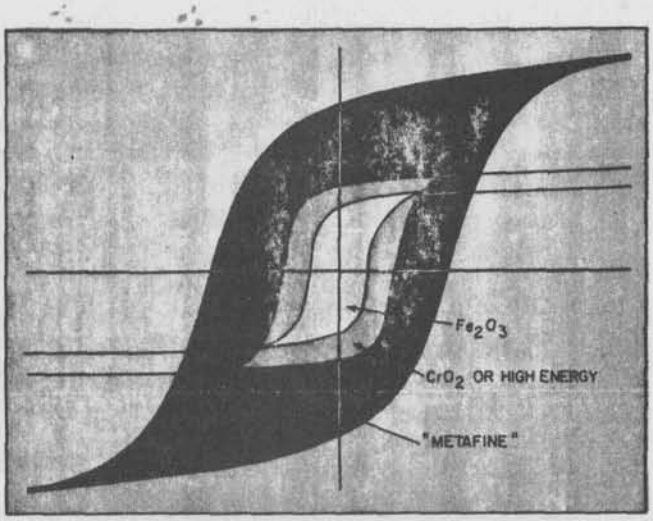
One effective way to implement GCR in a system is to use an intelligent interface, along with a 16-bit bidirectional bus to handle communication with a tape formatter. Such a system is available from Pertec, which calls it the Control/Data/CSD bus.

Commands go through the bus to an array of 16-bit registers located in the common access space (CAS). Each of the 16-bit CAS registers can be addressed via five CAS address lines. The host CPU talks to the formatter by addressing the appropriate CAS register.

When the host CPU receives information through the formatter, a read handshake operation brings the host status, interrupt and failure information from the formatter. This handshake operation, coupled with a bus structure, provides an efficient mode of communication between host CPU and GCR subsystem. All data flow is supervised by a microprocessor.



By recording four tracks at 1600 bits/in., the Model 200 from Qantex now provides 1.34 Mbytes of unformatted capacity. With the transport's 3 × 4 × 4-in. size, the data density is 28 kbytes/in.

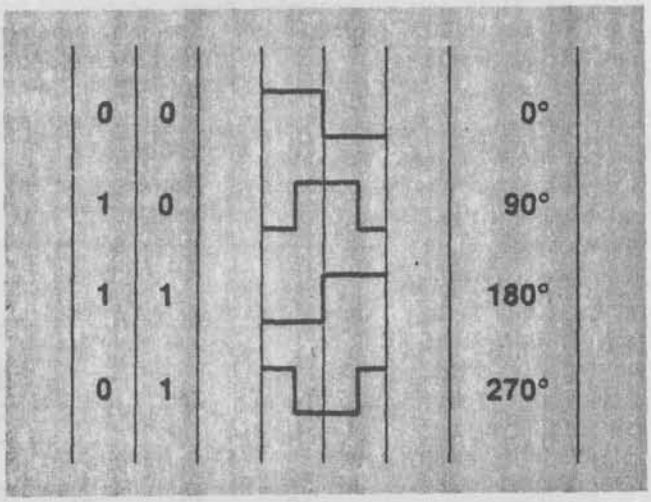


A tape coercivity of 1000 Oe enables 3M's Metafine tape to offer recording densities much larger than those offered by ferric or chromium-oxide tapes.

Microprocessor control is becoming increasingly popular in add-on magnetic-tape transports, too. A magnetic-tape transport for Data General, DEC and IBM minicomputers has been announced by Datum Inc. (Anaheim, CA). The D-451 is a single-board design that includes a dual-density formatter capable of radially controlling four drives, thereby eliminating daisy-chaining problems. Western Peripherals (Anaheim) will also announce a DEC-compatible tape controller this year.

A growing future

The more distant future looks even more promising for tape backup systems. New materials and encoding techniques will continue to increase tape capacity. Streaming digital tape will only get better, as



A digital-recording technique called Quadra-Phase by Spin-Physics can record densities as high as 120,000 bits/in. QP transmits two data bits/symbol. A symbol consists of one of four possible states.

Polar moment-of-inertia levels for IBM's 8809

Empty tape reel	
Reel diameter	**Polar moment of inertia**
6.25 and 7 in.	0.000480 ± 40% kg m²
8.50 in.	0.00114 ± 17% kg m²
10.50 in.	0.00250 ± 8% kg m²

Full Tape Reel			
Reel diameter	**Tape length**	**Polar moment of inertia**	**E-value***
6.25 in.	91.4–183 m (300–600 ft)	0.000859 ± 0.000213 kg m²	0.5 cm (0.2 in.)
7.00 in.	91.4–183 m (300–600 ft)	0.001356 ± 0.000231 kg m²	0.6 cm (0.2 in.)
8.50 in.	365.8 m (1200 ft)	0.00336 ± 0.00027 kg m²	1.0 cm (0.4 in.)
10.50 in.	731.5 m (2400 ft)	0.00867 ± 0.00042 kg m²	1.1 cm (0.4in.)

*E-value is defined as the radial distance that the reel flanges extend beyond the outermost layer of tape. The polar moment-of-inertia given above is invalid if the tape reel does not have the indicated E-value.

will digital data cartridges. Reliability and performance will improve, thanks to moving heads and more tracks per tape.

For example, twice the data-storage capacity now, and another quadrupling in the near future are the results of a new tape-head technology developed by Qantex (Hauppauge, NY). Eventually, 5.3 Mbytes of unformatted data will be squeezed into a 140-ft ¼-in. tape while the tape enclosure is kept down to 3 × 4 × 4 in. The net result will be a data density of 27,000 bytes/in³.

Right now, the head is undergoing two phases of development. In the initial phase, the new head is being constructed to maintain proper guard bands, narrow the track width, increase the number of tracks from two to four and yield a total storage capacity of 1.34 Mbytes. The second phase promises to increase storage density per track from 1600 to 6400 bits/in.

Another improved code for high-density digital recording is being developed by Spin-Physics (San Diego, CA). Called Quadra-Phase (QP), it makes efficient use of a channel bandwidth and yields a clock window equivalent to NRZ. What's more, QP has energy spectral zeroes at dc and a bit rate with maximum energy content in the mid-band region. This allows the channel to pass the signal with the least amount of distortion. And the lab results are dazzling: 120,000 bits/in.

Although QP is aimed primarily at instrumentation, Spin-Physics researchers feel that the code—which transmits two data bits per phase out of a possible four—will excel in high-speed digital recording with computer peripherals.

Another possible way to increase recording densities is metal-particle tape. Developed by 3M, Metafine tape—because of its high coercivity and retentive properties—can record much higher densities than conventional ferric or chromium-oxide tapes. Retentivity is 3400 gauss, well over the 1500 or less for oxide-type tapes. Moreover, coercivity is 1000 oersteds, compared to 550 Oe for chromium dioxide or cobalt-modified ferric-oxide tapes.

Currently, the metal tape is being used in audio applications, but its future could be digital. The only missing link, 3M researchers claim, is to develop digital tape drives and heads for metal tape.

Single-channel movable heads will also begin to impact digital tape-recording systems. For example, a bidirectional read-after-write head from Nortronics Inc. (Minneapolis, MN) can record as many as 16 data tracks when it is designed into a ¼-in. tape drive. The result? Double the recording density: a startling 12,000 bits/in.

Moving heads move in

The moving head is first positioned on the tape so that one track is recorded near the edge of the tape. Then, as the tape runs its course, the head automatically selects a new position, reverses itself and moves and records data in the opposite direction. What's more, a symmetrical tunnel erase allows closer track spacing and a subsequent reduction in noise level.

Several more movable heads are expected this year. The principal beneficiaries of the moving-head technique will be streaming drives like the DEI 34-Mbyte Microtape.

Meanwhile, even more packing density is expected from several sources. Research at IBM continues on an 18-track thin-film head, and streamer research has escalated at Storage Technology, Pertec and other high-performance-tape suppliers. Thin film heads are sure to be an important factor next year. Furthermore, tape tension, coatings and physical size will be scrutinized for the complete backup answer.

APPENDIX IV

INDUSTRY TRADE PRESS COVERAGE

Shugart Spin-out to Enter 8-Inch Mkt.

ELECTRONIC NEWS, MONDAY, MARCH 3, 1980

By JEFF MOAD

SAN JOSE, Calif. — Quantum Corp., a spin-out from Shugart Associates, which includes former Shugart manager of product management James M. McCoy, has been formed to enter the low-cost 8-inch fixed disk drive business against Shugart and Memorex, it has been learned.

President of the start-up company, which has temporary headquarters here, is James L. Patterson, former vice-president of engineering at System Industries Corp. Others at Quantum include former Shugart director of floppy disk engineering David A. Brown, former Shugart 8-inch engineering manager Joel Harrison, and former Shugart director of manufacturing engineering Harold C. Medley.

The company first surfaced last month when it was learned that Mr. McCoy and several others had left Shugart and were understood to be forming a company of their own (EN, Feb. 18). At that time, however, it was not known what type of business was planned.

Mr. McCoy will head Quantum's marketing effort, while Mr. Medley will oversee manufacturing. Mr. Brown will be responsible for engineering, and Messrs. Harrison and Daniels will report to Mr. Brown.

Mr. McCoy said first delivery of the Quantum 8-inch product will be in the second half of 1980. He said volume production of the product will begin by the start of 1981.

Interested in Financing

Mr. McCoy said Quantum officials are financing the company but that financing arrangements with venture capital companies and others are expected to be set soon. Mr. McCoy indicated that several small computer manufacturers and other potential OEM customers of the low-cost 8-inch product have expressed interest in finnacing Quantum.

Mr. McCoy recently left Shugart shortly after Messrs Harrison and Brown left the company. Speculation at that time touched on the possibility that Quantum would come up with a 5¼-inch fixed drive. Another Shugart spin-out, Shugart Technology, already has announced a 5¼-inch product, and Shugart and Memorex are believed to be studying the 5¼-inch market.

Mr. McCoy last week said that, while the 8-inch fixed disk drive will be Quantum's only product initially, it also plans to consider smaller fixed disk drives.

Mr. McCoy said that while over 20 different companies have indicated they will come up with an 8-inch fixed disk drive product, most of the competition seems to have a higher cost, higher capacity, closed loop technology product in mind. Quantum, said Mr. McCoy, will compete with Shugart and Memorex in the low-cost 5- and 10-megabyte 8-inch market where high volume production will be at a premium.

6 Months Behind

Both Shugart and Memorex are believed to be pushing for eventual volume production rates of 500 8-inch drives daily. Memorex, however, is believed to be at least 6 months behind in its 8-inch program. Shugart recently disclosed delivery of its 8-inch disk drive to Wang Labs, which is expected to be a major customer.

Mr. McCoy claimed that Quantum's engineering, marketing and manufacturing officials "have been in on the introduction of every new Shugart product, including the SA4000 and SA1000." Mr. McCoy predicted that "all of the ingredients are here in the 8-inch market that were there when floppies were undergoing their greatest growth." He said the 8-inch market will grow into a one-half million to one million-unit per year market within 5 years.

"We don't intend to bring any of the competition to their knees, but if it goes like many marketing experts predict, the 8-inch market will be spectacular," he said.

Mr. McCoy agreed, however, that the low-end 8-inch market will be highly price-competitive from the outset. Prices will be tied very tightly to costs. There will be no free rides or attractive umbrellas," Mr. McCoy said.

Computer Systems News — Monday, March 3, 1980

Ex-System Industries, Shugart Execs Establish 8-Inch Winchester Company

By Paul E. Schindler Jr.

SAN JOSE, CALIF. — A former System Industries, Inc., vice-president and five ex-Shugart Associates executives have started an 8-inch Winchester disk drive firm aimed at competing in the "super-low-cost" market segment.

James Patterson, former System Industries engineering vice-president and now president of the new firm, called Quantum Corp., sees the Winchester market "dividing into two segments: low cost and super-low cost. Only Shugart and Memorex are in the super-low-cost segment."

"It may look like a crowded marketplace," said James McCoy, who recently left his Shugart post as manager of product management (CSN, Data Flow, Feb. 18) to become Quantum's head of marketing. "There are at least 28 other firms in it. But we don't aim to be number 29; we are going to be number three in the lowest-cost segment."

Joining Patterson and McCoy are the other former Shugart executives: David Brown, previously floppy disk engineering director, who will be in charge of engineering, and Harold C. Medley, who had been director of manufacturing, engineerng and development and will now handle manufacturing.

Additionally, Joel N. Harrison, former engineering manager and project engineer for Shugart's SA1000 line, and Donald V. Daniels, previously Shugart's engineering manager for large fixed-disk drives, will serve on Quantum's engineering team.

First deliveries, according to Patterson, are expected in the second half of this year, with volume production by 1981.

The firm temporarily is based in headquarters here but plans to establish permanent quarters in the Santa Clara Valley, Patterson noted.

McCoy: Aiming For No. 3

Quantum's founders are all experts in production of "small, low-cost electromagnetic peripherals," according to Patterson, who said the firm eventually will produce a family of drives, perhaps including a less-than-8-inch Winchester.

There will be no new, innovative technology in Quantum's products, according to McCoy, who said, "The key to Shugart's success was to pull together mature technologies for a high-volume, low-cost operation."

Existing technologies can still be combined in ways that will "improve cost-performance," he predicted, but he declined to give details.

According to McCoy, Quantum's founders—most of whom have worked at IBM and Memorex—are "in their third-generation of low-cost, fixed-disk products."

Financing for the new firm is not completed, according to Patterson, who said negotiations are underway with venture capital firms and "innovative sources" of alternative financing. "We don't think money will be a problem," he said.

Product specifications are not completed, McCoy said, but the first drive will be in the low-capacity range. The interface has not been set, he added, but "if ANSI wins, much of the industry will go with it." He said the timing of Quantum's market entry will "allow us to position ourselves on a winning course" with regard to interfaces.

Quantum will not have a prototype at May's NCC, according to McCoy, but the firm will have "a presence" at the show.

Patterson said the search for an appropriate product began last September. "We examined many possibilities," he said.

He said he didn't want to detail the rejected options because "we concluded that none of them was a dead end."

Selecting the 8-inch drive market was a "difficult decision," according to Patterson, in view of the wide range of opportunities in peripherals. "All of them are boom markets, but all of them have big guns trained on them," he said.

McCoy and Patterson said they did not expect any confusion between their firm and the similarly named Quantum Science Corp., a marketing research firm, which performs no manufacturing.

Reminded of the high infant mortality of firms in the peripherals business, McCoy recalled the situation in floppy disks in 1974. "The projections of who would win then and who actually did turned out to be quite different," he said.

"Our market will range from very healthy to spectacular," he predicted.

THE WALL STREET JOURNAL, Tuesday, April 1, 1980

Memorex and Olivetti Form a Joint Venture For Disk Drive Units

By a WALL STREET JOURNAL *Staff Reporter*

SANTA CLARA, Calif.—Memorex Corp. said that it and Ing. C. Olivetti & C. S.p.A. of Italy formed a joint venture to make Memorex Model 101 drive units for rigid disks in an Olivetti facility in Ivrea, Italy.

Memorex also said that Olivetti will acquire a 10% interest in Memorex Mini Disc Drive Corp., a Memorex research and development subsidiary for eight-inch disks in San Jose, Calif.

Terms of the joint venture call for Memorex to supply advanced eight-inch disk-drive technology through a licensing agreement. Memorex also will supply selected disk-drive parts. Olivetti will provide local product support, management, facilities and working capital.

Memorex didn't disclose ownership interests, but Olivetti said it will own 60% of the joint venture and Memorex will own the remainder.

Manufacturing operations are expected to begin in the fourth quarter of this year in an existing Olivetti factory. The first disk drive to be made will be the 11.7 megabyte model, a measure of memory, that Memorex introduced last June. Shipments will begin in late 1980.

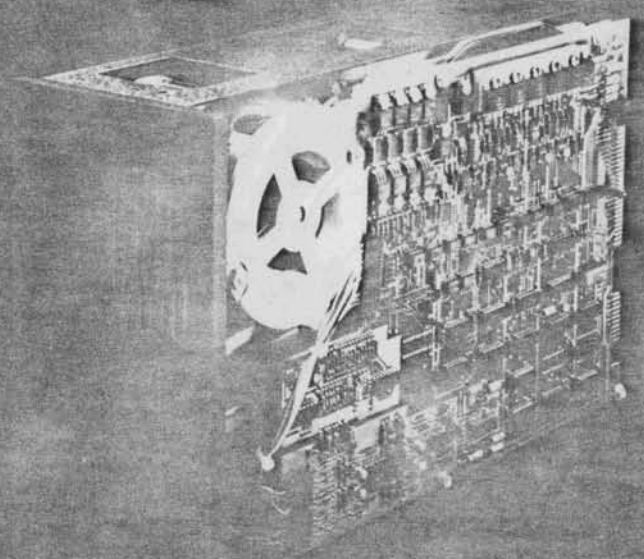
Memorex will market the disk under the Memorex name to its own customers, principally in Europe, and Olivetti will incorporate the disk in the business and accounting systems that it sells throughout the world.

APPENDIX V

COMPETING PRODUCT DATA SHEETS

Shugart

8-inch Fixed Disk Drive



The SA1000 Series of 8-inch fixed disk drives offers for the first time to OEM's proven Winchester fixed disk technology in a floppy size package. Available in 5 and 10 megabyte versions, the SA1000 drives are the lowest cost per megabyte Winchester drives in their capacity range.

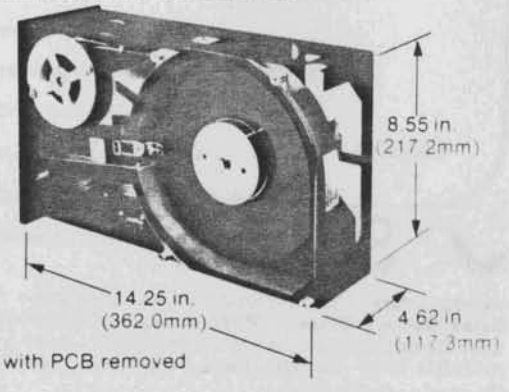
System enhancement with the SA1000 Series is simple and inexpensive. In addition to providing the same physical dimensions and mounting holes as an 8-inch Shugart floppy, the SA1000 features a simple interface using a command structure similar to a floppy drive. Drive control signals use the same pin assignments as the Shugart SA850 floppy drive, thus allowing the designer to daisy chain fixed and floppy drives in a system. In addition, software development is simplified because the track capacity of the SA1000 is the same as a double-density SA850.

DC voltage requirements are the same as floppy disk drives, permitting the use of a single power supply with both drives. The environmental specifications for the SA1000 are also identical to that of the Shugart 8-inch floppy drive.

Shugart's Fasflex III™ metal band actuator head positioning system operates with less power, is virtually wearproof, and requires no field adjustment or preventive maintenance. An optional data separator provides VFO data separation, write pre-compensation, a crystal write oscillator, and will support up to four SA1000 drives. Also available is an optional controller PCB.

Key Features

- 5.3 and 10.7 Mbyte (unformatted) storage capacity
- Identical mounting to either rack mounted or standard Shugart 8-inch floppy drives
- Lowest cost/megabyte 8-inch drive in its capacity range
- Winchester head and media technology
- Proprietary Fasflex III™ band actuator
- 4.34 Mbits/second transfer rate
- Simple interface similar to floppy
- Same DC voltages as Shugart's 8-inch floppies
- Optional data separator PCB available
- Optional controller PCB available



SA1000 with PCB removed

Specifications

Functional Characteristics

The SA1000 Fixed Disk Drive consists of read/write and control electronics, read/write heads, track positioning mechanism, spindle drive mechanism, disk(s), and air filtration system. These components perform the following functions:

Interpret and generate control signals
Move read/write head to the selected track
Read and write data

The electronics are packaged on one printed circuit board:

Read/Write Functions
1. Read Amplifier and Transition Detector
2. Read/Write Head Selection Circuit
3. Write Driver
4. Differential Line Drivers and Receivers

Actuator Driver Functions
1. Step Buffer
2. Velocity Ramp Profile Control
3. Head Position Actuator Drivers

Control Functions
1. Interface Drivers/Receivers
2. Drive Select Circuits
3. Write Fault Detection Circuits
4. Drive Ready Detector Circuit
5. Automatic restore to track 00 on power up

Drive Mechanism

The AC disk motor rotates the spindle at 3125 RPM through a belt-drive system. Either 50 or 60 Hz power is accommodated by changing the drive pulley and belt.

Air Filtration System

The disk(s) and read/write heads are fully enclosed in a module using an integral recirculating air system with an absolute filter which maintains a clean environment. A separate absolute breather filter permits pressure equalization with the ambient air without contamination.

Positioning Mechanism

The read/write heads are mounted on a ball bearing supported carriage which is positioned by the Fasflex III™ actuator. A stepper motor is used to precisely position the carriage assembly utilizing a unique metal band/capstan concept.

Read/Write Heads and Disk(s)

The recording media consists of a lubricated thin magnetic oxide coating on a 200mm dia. aluminum substrate. This coating formulation, together with the low load force, low mass Winchester type flying heads, permits reliable contact start/stop operation.

Data on each disk surface is read by one read/write head, each of which accesses 256 tracks. The drive is available in two basic configurations: one disk with two read/write heads, or two disks with four read/write heads.

Performance Specifications

Capacity	SA1002	SA1004
Unformatted		
Per Drive	5.33 Mbytes	10.67 Mbytes
Per Surface	2.67 Mbytes	2.67 Mbytes
Per Track	10.4 Kbytes	10.4 Kbytes
Formatted (SA850)		
Per Drive	4.2 Mbytes	8.4 Mbytes
Per Surface	2.1 Mbytes	2.1 Mbytes
Per Track	8.2 Kbytes	8.2 Kbytes
Per Sector	256 bytes	256 bytes
Sectors/Track	32	32
Transfer Rate	4.34 Mbits/sec	4.34 Mbits/sec
Access Time		
Track to Track	19 msec	19 msec
Average	70 msec	70 msec
Maximum	150 msec	150 msec
Average Latency	9.6 msec	9.6 msec
Functional Specifications		
Rotational Speed	3125 rpm	3125 rpm
Recording Density	6270 bpi	6270 bpi
Flux Density	6270 fci	6270 fci
Track Density	172 tpi	172 tpi
Cylinders	256	256
Tracks	512	1024
R/W Heads	2	4
Disks	1	2
Index	1	1

Physical Specifications

Environmental Limits
- Ambient Temperature = 50° to 115°F (10° to 46°C)
- Relative Humidity = 8% to 80%
- Maximum Wet Bulb = 78° non-condensing

AC Power Requirements
- 50/60 Hz ± 0.5 Hz
- 100/115 VAC Installations = 90-127V at 1.1A typical
- 200/230 VAC Installations = 180-253V at 0.6A typical

DC Voltage Requirements
- +24 VDC ± 10% 2.8A typical during stepping (0.2A typical steady state)
- +5 VDC ± 5% 3.6A typical
- −5 VDC ± 5% (−7 to −16 VDC optional) 2A typical

Mechanical Dimensions

	Rack Mount	Standard Mount
Height =	4.62 in. (117.3mm)	4.62 in. (117.3mm)
Width =	8.55 in. (217.2mm)	9.50 in. (241.3mm)
Depth =	14.25 in. (362.0mm)	14.25 in. (362.0mm)
Weight =	17 lbs. (7.7Kg)	17 lbs. (7.7Kg)

Heat Dissipation = 511 BTU/Hr. typical (150 Watts)

Reliability Specifications

MTBF: 8,000 POH typical usage
PM: Not Required
MTTR: 30 minutes
Component Life: 5 years

Error Rates
- Soft Read Errors: 1 per 10^{9} bits read
- Hard Read Errors: 1 per 10^{12} bits read
- Seek Errors: 1 per 10^{6} seeks

Shugart

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Sales/Service Offices:—West: Sunnyvale, CA (408) 737-9241, Costa Mesa, CA (714) 979-1935. **Southwest:** Dallas, TX (214) 234-3568
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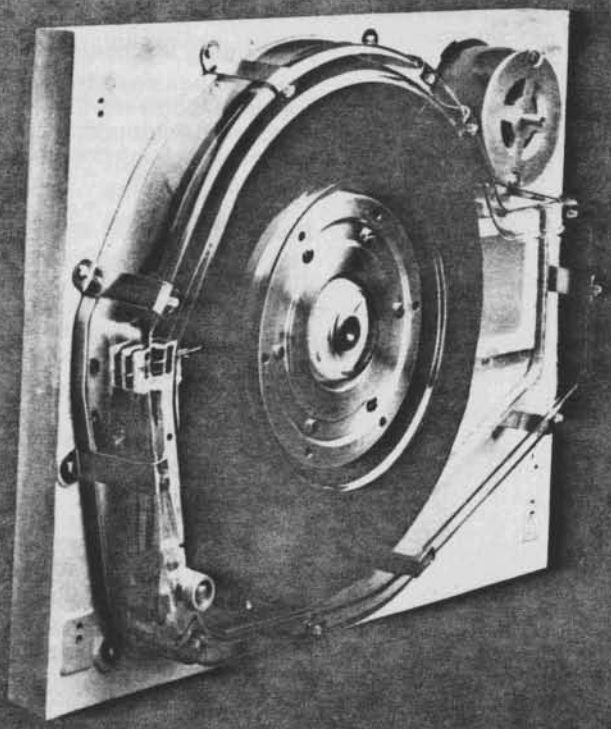
Shugart Associates

Fixed Disk Drive



SA4000 Series fixed disk drives are compact, low cost mass storage units utilizing proven Winchester head and media technology. They are available in 14.5 and 29 megabyte versions (unformatted) and offer the lowest cost per function mass storage capability in their capacity range. When used in a system with standard Shugart floppy disk drives, the SA4000 disk drives provide highly affordable storage that is compatible with IBM S/32, S/34, and System/1 system architectures.

SA4000 series features Shugart's new proprietary Fasflex II™ actuator which operates with low heat dissipation, is virtually wear-proof, and requires no field adjustment. The drives use only 5.25-inches of panel space, can be mounted in a 19-inch RETMA rack and weigh only 35 pounds. Significant savings can be realized in the design of the system interface and power supply. For example, SA4000 drives use a simple interface which is similar to that used in Shugart SA800 and SA850 floppy drives. In addition, a single power supply can be used for SA4000 fixed disk drives and floppy disk drives, since both drives have the same voltage requirements.

The fixed disk drives are available in two configurations: the Model SA4004 (14.4 Mbytes) utilizing one disk and four heads, the Model SA4008 (29 Mbytes) utilizing two disks and eight heads. Eight optional fixed heads are also available to provide an added 144 Kbytes (unformatted) of head-per-track storage for applications such as indexed files or table look-up.

Key Features

- 14.5/29 Mbyte (unformatted) storage capacity
- Winchester head and media technology
- Compact size—19-inch RETMA rack mountable using only 5.25 inches panel space
- Low weight (35 lbs.)
- Low heat dissipation (200 watts typical)
- 7.1 Mbits/second transfer rate
- Optional head-per-track storage—144 Kbytes
- Fully enclosed drive mechanism
- Proprietary Fasflex II band actuator

Specifications

Functional Characteristics

The SA4000 Fixed Disk Drive consists of read/write and control electronics, VFO data separator, MFM encode/decode electronics, read/write heads, track positioning mechanism, drive mechanism, disk(s), and air filtration system. These components perform the following functions:

Interpret and generate control signals
Move read/write head to the selected track
Read and write data

The electronics are packaged on four printed circuit boards:

Read/Write PCB
1. Read Amplifier and Transition Detector
2. Read/Write Head Selection Circuit
3. Write Driver
4. PLO Clock Amplifier

Actuator Driver PCB
1. Step Buffer
2. Head Position Actuator Driver

Control PCB
1. Interface Drivers/Receivers
2. Drive Select Circuits
3. Write Fault Detection Circuits
4. Byte (sector optional) Clock Generation Circuit
5. Drive Ready Detector Circuit
6. PLO Clock Detection Circuit

Data Separator PCB
1. Data Separator
2. MFM Encode/Decode Circuit

Drive Mechanism

The disk drive motor rotates the spindle at 2,964 RPM through a belt-drive system. 50 or 60 Hz power is accommodated by changing the drive pulley and belt.

Air Filtration System

The disk(s) and read/write heads are fully enclosed in a module using an integral recirculating air system with an absolute filter which maintains a clean environment. A separate absolute breather filter permits pressure equalization with the ambient air without contamination.

Positioning Mechanism

The read/write heads are mounted on an arm which is positioned by the Fasflex II™ actuator. A stepping motor is used to precisely position the head/arm assembly through the use of a unique metal band/capstan concept.

Read/Write Heads and Disk(s)

The recording media consists of a lubricated thin magnetic oxide coating on an aluminum substrate. This coating formulation, together with the low load force/low mass Winchester type flying heads, permits reliable contact start/stop operation.

Data on each disk surface is read by two read/write heads, each of which accesses 202 tracks. The drive is available in two basic configurations: one disk with four read/write heads, or two disks with eight read/write heads.

A separate read/write head mounted to the base casting reads a prerecorded track which provides the master clock for the drive and write clock generation.

The optional fixed heads are mounted on an assembly which is mounted directly on the base casting.

Performance Specifications

Capacity	4004	4008
Unformatted		
Per Drive	14.5 Mbytes	29.0 Mbytes
Per Surface	7.3 Mbytes	7.3 Mbytes
Per Track	18 Kbytes	18 Kbytes
Formatted (IBM S/32)		
Per Drive	12.4 Mbytes	24.8 Mbytes
Per Surface	6.2 Mbytes	6.2 Mbytes
Per Track	15.4 Kbytes	15.4 Kbytes
Per Sector	256 bytes	256 bytes
Sector/Track	60	60
Transfer Rate	889 Kbytes/sec.	889 Kbytes/sec.
Seek Time		
Track to Track	20 msec	20 msec
Average	87 msec	87 msec
Maximum	220 msec	220 msec
Average Latency	10.1 msec	10.1 msec

Functional Specifications

Rotational Speed	2,964 RPM	2,964 RPM
Recording Density	5,534 BPI	5,534 BPI
Flux Density	5,534 FCI	5,534 FCI
Track Density	172 TPI	172 TPI
Cylinders	202	202
Tracks	808	1,616
R/W Heads	4	8
Disks	1	2
Physical Sectors	Programmable	Programmable
Index	1	1
Encoding Method	MFM	MFM

Physical Specifications

Environmental Limits
Ambient Temperature = 50° to 105°F (10° to 41°C)
Relative Humidity = 8% to 80%
Maximum Wet Bulb = 78°F non-condensing

AC Power Requirements
50/60 Hz ± 0.5 Hz
100/115 VAC Installations = 90—127V at 1.5A typical
200/230 VAC Installations = 180—253V at .8A typical

DC Voltage Requirements
+24 VDC ± 10% 2.5A typical
+ 5 VDC ± 5% 2.5A typical
−7 to −16 VDC (optional −5 VDC ± 5%) .1A typical

Mechanical Dimensions (exclusive of front panel)
Height = 5.1 in. (129.5mm)
Width = 16.6 in. (421.6mm)
Depth = 21.9 in. (556.3mm)
Weight = 35 lbs. (15.9Kg)

Heat Dissipation = 682 BTU/hr. typical (200 Watts)

Reliability Specifications

MTBF: 5,000 POH typical usage
PM: Not required
MTTR: 30 minutes
Component Life: 5 years
Error Rates:
Soft Read Errors: 1 per 10^{10} bits read
Hard Read Errors: 1 per 10^{12} bits read
Seek Errors: 1 per 10^{6} seeks

Shugart Associates

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5 78 Printed in U.S.A.

101 OEM Disc Storage Drive
Future Product Information

Because Memorex is committed to supporting the OEM market with the highest quality products, we are continually researching and updating our present products to incorporate the latest technology. By combining Winchester-type technology with proven design techniques, the original equipment manufacturer is ensured of the ultimate in reliability and quality from Memorex. The OEM customer is further supported by the finest field service organization in the industry.

The Memorex 101 is an eight-inch, rigid disc, data storage module that fits into a flexible disc drive envelope providing 11.7 MB of storage capacity. Features and benefits include:

- Flexible disc size
- High-speed band actuator
- Imbedded drive spindle motor
- Sealed media environment
- Low heat dissipation
- Low power requirements

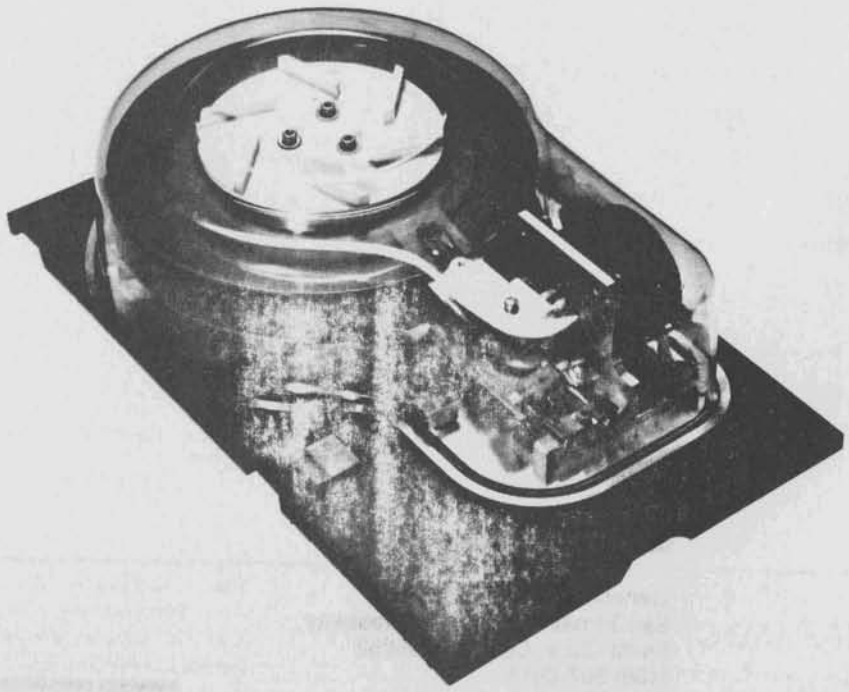
The Memorex 101 incorporates a flexible disc electrical interface and physical mounting pattern allowing the 101 and the flexible disc drive to share the same controller, cabinet, and power supply.

Memorex engineers have designed a new high-speed band actuator that requires no field adjustments and has a very low heat dissipaiton.

By integrating the drive motor with the hub, we have eliminated belts and lowered parts count which increases reliability and saves valuable space. The electronics package mounts to the bottom of the head/disc assembly (HDA) for easy field service access even while the drive is running.

A carefully designed sealed environment protects the head, media, actuator, and spindle from contamination and utilizes an absolute filtration system inside the enclosure.

Less than 100 watts of power are required to operate the Memorex 101 which lowers system costs. What's more, only DC power is necessary allowing for international versatility.



MEMOREX

101 OEM Disc Storage Drive
Future Product Information

MEMOREX

101 OEM Disc Storage Drive
Future Product Specifications

Capacity
Drive: 11.7 MB
Per Surface: 2.9 MB
Per Track: 12,000 BYTES

Data Retrieval Times
Track-to-Track Access Time: 20 MS
Average Access Time: 70 MS
Maximum Access Time: 120 MS
Average Latency: 10.1 MS

Dimensions
Width: 8.55 inches
Height: 4.38 inches
Depth: 14.0 inches

Weight
20 lbs.

Power Requirements:
Voltage: +24 VDC ± 10% @ 7A
+ 5 VDC ± 5% @ 2A
− 5 VDC ± 5% @ 250 MA

Environment
Ambient Temperature: 50° to 120°F
Relative Humidity: 10% to 90%

Specifications
Rotational Speed: 2964 RPM
Cylinders: 244
Heads: 4
Physical Sectors
Encoding Method MFM
Index: 1
Sectors/Track
256 Bytes/Sector: 64
up to 4096 Bytes/Sector: 32
128 Bytes/Sector: 128
Interface: Flexible Disc Compatible

Reliability Specifications
Fixed Disc
MTBF: 8000 hrs.
MTTR: 30 min.
Error Rate
Soft Read Error: 1 per 10^{10}
Hard Read Error: 1 per 10^{12}
Seek Error: 1 per 10^{6}

101 OEM Disc Storage Drive
Future Product Information

Memorex Corporation

General Systems Group
San Tomas at Central Expressway
Santa Clara, California 95052
(408) 987-0605
Telex: 346-442

APPENDIX VI

MANAGEMENT TEAM RESUMES

James L. Patterson
1158 Tillman Ave.
San Jose, CA 95126

RESUME SUMMARY

Graduate Electrical Engineer, University of Colorado - 1960

20 years of experience in Engineering, Product Development Business and Market Planning, including 15 years in General Management. All of the experience has been associated with High Technology Data Processing Equipment.

Product Development Programs have included:

- Disk Drive Subsystems
- Ink Jet Printers
- Clinical Laboratory Data Systems
- Scientific Instrument Data Systems
- IBM Compatible Communication Controllers
- CRT Terminals
- Central Processing Units
- Microfilm Printers
- High Speed Non-Impact Printers
- Process Control Systems
- Punched Card Equipment

Product and Business Planning have included:

- IBM Compatible Disk and Tape Drives
- O.E.M. Disk Drives
- Process Control Peripheral Equipment

Employment History:

- Independent Constant
- System Industries
- Memorex Corporation
- IBM Corporation

EXPERIENCE

Independent Consulting

1979 to 1980 - Business and Product Planning in O.E.M. Disk Products, Precision Electronic Balances and Mass Storage Subsystems for several companies manufacturing high technology products. Assignments included evaluation of peripheral equipment, forecasting sales of new products and definition and specification of market requirements.

System Industries

1973 to 1979 - 1978 - 79, V.P. of Engineering. Responsible for all of the product development and technical activities. The engineering department included approximately 35 Engineers, Programmers,Technicians and Support people. The products developed included Disk Storage Subsystems with requisite operating system software. The Disk Subsystems attached to Digital Equipment Corporation (DEC) and Data General (DG) Computer Systems and were sold into the end user market as well as the O.E.M. Markets. The System Industries product consistently out-performed the equivalent DEC and DG products and were offered substantially lower prices.

1977 - 78, General Manager of Silonics Corporation, (a subsidiary of System Industries and Konishiroku, a Japanese Company) with responsibility for the product and technology development, manufacturing and marketing of an Ink Jet Terminal Printer. During this period the printer was developed from a feasibility model through the release to manufacturing. The product was formally introduced to the market and production was initiated. Units were delivered to several large O.E.M. for evaluation. This product is currently being manufactured by both System Industries and Konishiroku.

1973 - 77, V.P. of Engineering for System Industries. Responsible for all of the company's product development activities. The engineering efforts included research in Ink Jet Printing, Disk System product, Clinical Laboratory Data Systems, and Scientific Instrument Data Systems. During this period products were developed and released to manufacturing which resulted in the company's growth from $2.5 million in 1972 to $25 million in 1979.

Memorex Corporation

1970 to 1973 - 1972 - 73, Director Engineering with Product Development responsibility for Communications Terminals, Terminal Control Units, Modems, and Central Processing Units. The Engineering Group included 60 people; primarily working in Engineering and Technical Fields. New Product Development included a central processor and a terminal control unit compatible with IBM's 3705. In addition to new Product Development the group performed continuation engineering supporting a large base of communication products in manufacturing and in the field.

1970-72, Director of Product Planning with responsibility for Memorex's product planning in Microfilm and Disk Products. Activities included Surveys of Customer Needs, Definition of Market Requirement, New Business Analysis and Sales Forecasting.

IBM Corporation

1964 to 1970 - 1969-70, Senior Engineer on the staff of the Laboratory Director. Participated in numerous project and program reviews, assisted in the formulation of Laboratory Operating Plans, including coordination with other IBM Laboratories.

1967-69, Senior Engineer and Manager of Electronic Development for the Advanced Printer Program. The development activities included control of the Electro-Mechanical Process and Control Unit Functions associated with attachment to IBM Systems.

1964-67, Manager of Product Development, Process Control systems with responsibility for Central Processor and Data Collection Peripherals and Terminals. Products successfully introduced included the IBM 1800 System and associated peripheral equipment.

1960-64, Various Engineering and Management assignment in Logic and Circuit Design associated with Punched Card equipment.

David Alan Brown
13751 Beaumont Ave.
Saratoga, CA 95070
(408) 867-2476

RESUME SUMMARY

Graduate Mechanical Engineer

MSME University of Santa Clara - 1974
BSME San Jose State - 1968

Twelve years experience in Engineering Research and Development with three years managing development programs for high technology products in rotating memory computer peripherals.

Product Development Programs have included:

- Paper Tape punches and readers
- Impact Printers
- Nonimpact Printers
- Various "Flying Head "Technologies"
- Alloy "Contact" Recording Heads
- Ceramic "Contact" Recording Heads
- Flexible Disk Drives

Management Experience:

First, Second, and Director level of Engineering Management.

Employment History:

- Shugart Associates
- Memorex Corporation
- Peripheral Data Machines
- Pratt & Whitney Aircraft

EXPERIENCE

Shugart Associates; Sunnyvale, CA

5-79 to Present — Director of Engineering: Flexible Disc Products: Responsible for Development of new flexible disc products and support of existing products.

1978 - 1979 — Manager of Mechanical Engineering: Responsible for mechanical engineering of floppy disc products.

1977 - 1978 — Project Manager: Responsible for double sided mini floppy development.

1975 - 1977 — Senior Project Engineer: Responsible for SA400 minifloppy program and all dynamic components. Responsibilities included:

- Development, manufacturing and product engineering through shipment of approximately 20,000 units.

1973 - 1975 — R/W Head Development Engineer: Responsible for design and process development of alloy and ceramic flexible disc R/W heads.

Memorex Corporation; Santa Clara, CA

1972 - 1973 — Mechanical Engineer: Responsible for Design and Product Engineering of Rigid Disk Flying Heads.

1970 - 1972 — Mechanical Engineer: Responsible for Development of all flexible disc dynamic assemblies and drive architecture.

Peripheral Data Machines; Santa Anal, CA

1969 - 1970 — Mechanical Engineer: Developed low cost paper type punch and reader and various components of low cost impact printer.

Pratt & Whitney Aircraft; East Hartfort, Conn.

1968 - 1969 — Mechanical Engineer: Responsible for theoretical analysis of gas turbine thermodynamic cycles. Analysis was accomplished via computer simulation.

David Alan Brown

EDUCATION

University of Santa Clara - 1974 MSME

San Jose State University - 1968 BSME

PERSONAL DATA

Born:	Oakland, CA; April 3, 1945
Home Address:	13751 Beaumont Ave. Saratoga, CA 95070
Home Phone:	(408) 867-2476
Marital Status:	Married - 2 children

INVENTION RECORD

Issued Patents:	3,964,103	- Magnetic Transducer with Trim Erase
	3,815,150	- Flexible Disc Drive
	3,863,395	- Apparatus for Polishing a Special Surface on a Magnetic Recording Transducer
Design Patents:	249,346	- Flexible Disc Drive
Patent Applied For:		- An Improved Floppy Disc R/W Head Positioning Apparatus

James M. McCoy
360 Menlo Oaks Drive
Menlo Park, CA 94025
(415) 323-5607

RESUME SUMMARY

Bachelor of Science - Industrial Engineer and Management - San Jose State University - 1969

Thirteen years total experience in Manufacturing Engineering, Manufacturing Management, and Marketing in magnetic recording products - Four years of Marketing and Product Management in low cost computer peripherals.

Manufacturing Engineering projects have included:

- IBM 2301, 2311, 2314, 3330 & 2305 magnetic heads
- Ferrite and Alfesil video and floppy disk heads
- Quarter-inch and .150-inch tape data cartridges

Manufacturing Management programs have included:

- Video, audio, and floppy disk heads
- Precision plastic video tape cartridges
- Data cartridges
- Video - cartridge recorders

Marketing Management responsibilities have included:

- Data cartridge and floppy disk media
- Floppy disk drives
- Low cost fixed disk drives

Employment History:

- Shugart Associates
- Verbatim Corporation
- Information Magnetics Corporation
- AVCO/Cartridge Television
- IBM Corporation

James M. McCoy

EXPERIENCE

Shugart Associates; Sunnyvale, CA

1979 - 1980 Manager of Product Management - Marketing: Responsible for all internal product, business and strategic planning, program management, sales support, field engineering, advertising and public relations. Managed a team of 35 Product Managers, Field Engineers and support people.

1978 - 1979 Product Line Manager - 8-inch Floppy Disk Drives: Responsible for product management for Shugart Associates' single and double sided 8-inch floppy disk drives. Appointed to lead corporate task force to improve production rate, quality, and cost of the SA-850 double sided drive.

Verbatim Corporation; Sunnyvale, CA

1976 - 1978 Product Manager - Marketing: Responsible for product planning and sales support for Data Cartridge products. Launched a new mini-cartridge product program.

1975 - 1976 Project Manager - Manufacturing - Built a team to manufacture Data Cartridge products. Responsible for all start-up activities including negotiation of technology license with 3M Corporation.

Information Magnetics; Santa Barbara, CA

1973 - 1974 Product Group General Manager: P & L responsible for Mini-Peripheral Heads Product Group. Managed manufacturing, Q.C., engineering, materials and sales support for floppy disk and cassette heads.

AVCO/Cartridge Television; San Jose, CA

1972 - 1973 Manager of Manufacturing: Directed a staff of 500 people in the U.S. and Singapore to manufacture magnetic heads and pre-recorded video tape cartridges.

1970 - 1972 Manager of Magnetic Head Manufacturing: Build a team to manufacture high volume, low cost video and audio recording heads. Responsible for all head operations including establishment of an assembly plant in Singapore.

IBM Corporation, San Jose, CA

1967 - 1970 Manufacturing Engineering: Responsible for tooling, process development, and manufacturing support for various magnetic head assemblies used in IBM disk and drum memories. Established operations for ferrite machining and testing. Assigned to component engineering to assist in developing an early IBM Manufacturing Information System for production and material requirements planning.

James M. McCoy

EDUCATION

San Jose State University, San Jose California 1964-1971
BSIE & Management - 1969

MILITARY EXPERIENCE

USAF Res - Staff Sergeant - Pharmacy Specialist 1967-1973

PERSONAL DATA

BORN: Cheyenne, Wyoming, July 25, 1946
HOME ADDRESS: 360 Menlo Oaks Drive
Menlo Park, California 94025
HOME PHONE: (415) 323-5607

Harold Medley
18631 Blythswood Dr.
Los Gatos, CA 95030
(408)354-8259

RESUME SUMMARY

Graduate Mechanical Engineer; Ohio State - 1950

Registered Professional Manufacturing Engineer; Calif. No. 4303

29 years experience in Engineering Research and Development with 12 years managing development programs for high technology products in computer peripheral and business machines fields and 2 years managing Manufacturing Engineering and Plant Facilities.

Product Development Programs have included:

- Xerographic printers
- Non-impact printing
- Impact printers
- Microfilm equipment (COM)
- Communications Terminals
- Floppy disk drives

Manufacturing Engineering:

- High volume manufacture of floppy disk drives

Employment History:

- Shugart Associates (Xerox)
- Memorex Corporation
- IBM Corporation
- Stromberg Datagraphix
- Battelle Institute
- Phillips Petroleum

EXPERIENCE

Shugart Associates; Sunnyvale, CA

1978-79 Director of Engineering: Flexible Disk Drive Products: Responsible for development of new floppy products and support of existing products.

1976-78 Director of Manufacturing Engineering: Responsible for vendor tools, development and build of factory tools, industrial engineering, material handling; also responsible for facilities.

1975-76 Manager of Mechanical Engineering: Responsible for mechanical engineering of floppy disk products.

1973-75 Senior Engineer: Participated in design of low speed low cost line printer, redesign of floppy drive components.

Memorex Corporation; Santa Clara, CA

1971-1970 Director of Engineering Ancillary Equipment: Responsible for development effort on all microfilm ancillary equipment in the Memorex COM System including: viewers, viewer printer, film processors, film duplicators; also initiated development effort in microfiche camera (PISCES) and automatic roll film retrieval system.

1970 Manager Viewer/Printer Project: Directed product development effort from conception through release to manufacturing and field support on cassette system roll film viewers; directed OEM effort on procurement of microfilm to hard copy viewer-printer.

IBM Corporation; San Jose, CA

1969 Manager (Senior Engineer) Process Development, Advanced Printer Development Program (Jubilee): Responsible for design and development of xerographic process components for a high speed non-impact computer output printer.

1968 Manager (Senior Engineer) Advanced Engineering Development, OPD Advanced Technology: Responsible for components development and technology support for the xerographic office copier development effort at IBM Lexington.

1967 Development Engineer: Responsible for solution of photographic film cleaning problem and contamination control on the Photo-digital Storage System (CYPRESS).

1966 Manager (Development Engineer) Electrophotography Group, SDD Advanced Technology: Developed xerographic camera for Advanced Systems Development; managed evaluation of "Games" oil distribution printing process for Publishing Systems.

1965-64 Manager (Development Engineer) Summit Program: Responsible for product development of a microfilm to hard copy printer using charge transfer technology (project was abandoned).

Manager of Summit II Program: Developed the basic plain paper technology for the IBM office copier.

1963-60 Staff Engineer, Photo Data Processing Group, SDD Advanced Technology: Materials and process evaluation and sensitometry covering electrophotography, charge transfer, vesicular films, diazo films, photo storage and retrieval technology.

Stromberg Carlson (now Stromberg Datagraphix); San Diego, CA

1960-58 Section Head, Mechanical Engineering: Responsible for mechanical engineering on all company projects covering; electronic packaging, mechanism design, cameras, projectors, optical systems, xerographic process, film processors.

IBM Corporation; Endicott, N.Y.

1958-54 Associate Engineer, Electrostatic Printer development: Research and development in xerographic IBM card to card printer and IBM card to label printer; engineering field support of first installation at Time Inc.

Battelle Memorial Institute; Columbus, Ohio

1954-52 Principal Mechanical Engineer: Research and development in continuous tone xerography; developed 13 second xerographic camera.

Phillips Petroleum Company; Borger, Texas

1952-50 Mechanical Engineer, Natural Gas Dept.: Design and construction of natural gas pipe line gathering systems.

Consolidated Vultee Aircraft Corp. (now Corvair); Fort Worth, Texas

1950 Junior Engineer, Armament and Photography Section: Drafting and design on gun turrets and camera installations in the B-36 Bomber.

EDUCATION

Texas Technology College; Lubbock, Texas		1947
Ohio State University; Columbus, Ohio		1947-1950
	BME	June, 1950

Honors: Pi Tau Sigma, Tau Beta Pi

MILITARY EXPERIENCE

World War II, U.S. Navy - 3½ years

PERSONAL DATA

Born:	Newcomerstown, Ohio; September 24, 1923
Home Address:	18631 Blythswood Drive Los Gatos, California 95030
Home Phone:	(408) 354-8259

INVENTION RECORD

Issued Patents:	3,063,351	Xerographic Powder Image Transfer Apparatus
	3,162,104	Deformation Image Development Apparatus
	3,240,596	Electrophotographic Process and Apparatus
	3,626,084	Deformographic Storage Display Tube
	3,666,518	Development Means and Methods for Developing Electrostatic Images
	3,898,814	Mechanism for Clamping and Driving a Flexible Disk
	3,939,768	Character Belt Apparatus with Replaceable Slugs for Line Printer
	4,040,106	Flexible Magnetic Disc Drive Apparatus
Design Patents:	245,125	Flexible Magnetic Disc Cartridge
	249,346	Flexible Disk Drive

Donald Daniels
119 Vine Hill Rd.
Santa Cruz, CA 95065

RESUME SUMMARY

Graduate Electronic Engineer, San Jose State - 1965

15 years experience in Development with 5 years Managing Development Programs with emphasis in development and manufacturing phases of product design. Extensive experience in analog design including servos, Read/Write, and rotating memory control circuitry.

Product Development Programs have included:

IBM 3330 Disk Drive

Microfilm Printer (COM)

CRT Terminals

Impact Printers

Floppy Disk Drives

Rigid Fixed Disk Drives

Employment History:

Independent Design Consultant

Shugart Associates (Xerox)

Memorex Corporation

IBM Corporation

EXPERIENCE

Electronic Design Consultant

1978 to Present
- Product Design Consultant for low cost disk drive. Provided recommendations for electronics packaging, drive interface and testing.
- Step motor drive design.
- Test system design for evaluating thermal "off track" for disk drive with a resolution of 10 micro inches.
- Presion A/D converter design and servo design for an analytical instrument.
- Design review of client's A/D conversion system - identified failure modes, design improvements and recommended changes which improve manufacturability.

Senior Engineer/Manager - Shugart Associates

1973 to 1978
- Project Manager, product definition through manufacturing start-up for the SA 4000 Fixed Disk Drive. Included planning, staffing, design and manufacturing, and customer interfacing. Directed efforts to 6 to 8 people.
- Electrical Project Leader - Digital and analog design of the SA 800 Floppy and SA 400 Mini-Floppy Disk Drives.
- Test equipment design, ranging from data separators to PCB test systems.
- Customer support including direct customer technical support, field trips, and field manual preparation.

Senior Engineer/Manager - Memorex Corporation

1968 to 1973
- Project Manager for 10,000 LPM Microfilm Printer. Design of analog circuits and direction of electrical and mechanical efforts - 8 to 12 people.
- Design of video circuits and low cost switching power supply for a CRT terminal.
- DC Motor servo design for a Microfilm reader.

- Product support engineer for Modems, including IBM compatable Modems and Memorex equivalent 202C Modem.

- Study and design of an advanced laser system for a high speed Microfich Printer.

Senior Associate Engineer - IBM Corporation

1965 to 1968

- Track following and seek servo design for the IBM 3330 Disk Drive.

- Sector separator design for the 2311 Disk Drive.

EDUCATION

- BSEE, San Jose State University, 1965

- Other courses:
  - Linear and Non Linear feedback control, IBM, 1967
  - Logic Design Synthesis, IBM, 1967
  - Micro Processor System Design, UCLA, 1975

INVENTION RECORD

1972 - Patent No. 3,688,656 Microfilm Printer

1973 - Patent No. 3,768,714 Microfilm Printer

1978 - Patent No. 248,346 Flexible Disk Drive

Joel N. Harrison
1190 Archer Way
Campbell, CA 95008
(408) 378-2495

RESUME SUMMARY

Graduate Mechanical Engineer

MSME Cal Tech - 1974
BSME Cal Poly - 1973

5 1/2 years experience in Engineering Research and Product Development, including 1 1/2 years as Manager of a Disk Drive development project.

Product Development Programs have included:

Eight inch diameter fixed Disk Drives

Fourteen inch diameter fixed Disk Drives

Disk Pack Disk Drives

Fixed/Removable Cartridge Disk Drives

Optical Scientific Instruments

Employment History:

Shugart Associates (Xerox)

Hewlett Packard Company

EXPERIENCE

Shugart Associates; Sunnyvale, CA

3-78 to 2-80 Engineering Manager for the SA1000 eight-inch diameter fixed Disk Drive.
Accomplishments include:

- Staffing of complete Design Team
- Demonstrating feasibility of initial design concepts
- Planning and meeting a very aggressive program schedule
- Achieving a projected product cost significantly below target
- Coordinating product design for future automated assembly capability
- Release of engineering documentation
- Supporting initial production activities

Hewlett Packard Company

Scientific Instruments Division; Palo Alto, CA

6-77 to 3-78 Development Engineer on State of the Art Optical Chemical Analysis Instrument (HP 8450A Spectrophotometer).
Accomplishments include:

- Design of a moving mirror servomechanism structure through computer modeling and experimentation
- Design of a printed circuit motor and optical position transducer
- Design of servo loop compensation
- Manufacturing process development for miniature optical components

Disk Memory Division; Cupertino, CA

6-74 to 6-77 Development Engineer on HP 7960A Removal Disk Pack Drive.
Accomplishments include:

- Responsible for stabilizing track following servo system through:
  . computer modeling of loop compensation
  . structural design
- Responsible for Head tracking precision
- Developed manufacturable Actuator
- Conceived/developed simple Spindle Rotation Lock

Product Engineer
Two Product Family of Cartridge/Fixed Disk Drives.

- Brushless DC Spindles
- Disk Cartridge/Spindle Interface Development

MILITARY EXPERIENCE

U.S. Navy Reserve - Two years Active Duty

PERSONAL DATA

Born:	Stockton, CA; October 25, 1947
Home Address:	1190 Archer Way Campbell, CA 95008
Home Phone:	(408) 378-2495
Marital Status:	Married - 2 children

APPENDIX VII

MANAGEMENT TEAM REFERENCES

Professional References Quantum Founders

James L. Patterson

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IBM Fellow
IBM Corporation
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David A. Brown

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President
Data Management Lab
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Harold C. Medley

Ted Hider
Senior Engineer
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Sunnyvale, California 95120
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James M. McCoy

Jim Porter
Publisher-Consultant
Disk/Trend Report
1224 Arbor Court
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President
Data Electronics Inc.
10150 Sorrento Valley Road
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Cliff Akers
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435 Oakmead Parkway
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Memorex Fellow
Memorex Corporation
San Tomas at Central Expressway
Santa Clara, California 95052
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Joel N. Harrison

Herbert Stickel
Engineering Manager
Hewlett-Packard Company
1601 California Avenue
Palo Alto, California 94304
(415) 493-1311

Robert Nordman
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Hewlett-Packard Company
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APPENDIX VIII

BIBLIOGRAPHY

BIBLIOGRAPHY

Market research sources include:

- Small Business Systems
  - IDC (International Data Corporation) Desktop Computer Market, Sept. 1979 #2024
  - Dataguest - Small Computer Industry Service January 15, 1980
- Personal Computers
  - IDC - (above)
  - Creative Strategies - Small Bus Computers 1979
- Word Processing Systems
  - Dataquest - Research Newsletter - 17 August 1979
  - Creative Strategies - May 1979
- Intelligent Terminals
  - Disk/Trend (James Porter) - 1979 Disk/Trend Report and personal interviews.
- Mini-Micro Computers
  - IDC - EDP Grey sheet - June 1979
  - Dataquest - Research Newsletter - 22 & 25 January 1980

Comparative disk drive market forecast sources include:

- Disk/Trend (James Porter)
- Venture Development Corporation
- Roman Associate
- Freeman Associates

APPENDIX IX

LEGAL CORRESPONDENCE

LAW OFFICES
OWEN, WICKERSHAM & ERICKSON
A PROFESSIONAL CORPORATION
PATENT, TRADEMARK & COPYRIGHT LAW
433 CALIFORNIA STREET, 11TH FLOOR
SAN FRANCISCO, CALIFORNIA 94104
(415) 781-6361

MELVILLE OWEN
ROBERT E. WICKERSHAM
ROGER W. ERICKSON
DAVID B. HARRISON
THOMAS M. FREIBURGER
ROBERTA L. CAIRNEY

A. DONHAM OWEN
(1900-1973)

TELEX: 470275 OWAE UI
CABLE: OWEPATMARK

March 27, 1980

James L. Patterson, President
Quantum Corporation
120 Charcot Avenue
San Jose, California 95131

Re: Xerox/Shugart

Dear Jim:

We have received a letter from Tom Webster on behalf of Xerox, copy enclosed. The letter in my view sets forth a hopeful tone. It directly or inferentially establishes the following points:

1. Xerox will not object to representation by Quantum that its principles met with Xerox representatives to review possible conflicts of trade secret and proprietary information.

2. At this time Xerox has no reason whatsoever to believe that Quantum or its employees who are former employees of Shugart have violated any trade secret information rights of Xerox.

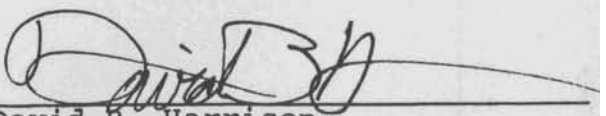
3. Shugart's "proprietary information" is no broader than the information categories enumerated. This is so even though the letter reads "without limitation". We have this view because if they could think of some other category, they probably would have put it in there.

4. The categories set forth in the second paragraph of Mr. Webster's letter seem sufficiently limited to us so that Quantum could and should live with them. We believe that you and your staff should be very careful about comparative advertising at this point, or revealing anything about Shugart other than that which you can document from publicly disclosed sources.

I understand from Joe that things are proceeding very well, and the receipt of this Xerox letter is another favorable sign in our view. Keep up the good work and let us know if we can be helpful. Best wishes.

Sincerely,

Owen, Wickersham & Erickson

By 
David B. Harrison

DBH:ss
Enclosure

Xerox Corporation
3333 Coyote Hill Road
Palo Alto, California 94304
415 494-4000

Office of General Counsel

XEROX

March 26, 1980

David B. Harrison, Esq.
Owen, Wickersham & Erickson
433 California, 11th Floor
San Francisco, California 94104

Dear Mr. Harrison:

We have your letter of March 7, 1980.

We understand that you may want to advise others that you met with us. We met because the presence of a number of former Shugart/Xerox employees on Quantum Corporartion's staff and the anticipated overlap in the products of Quantum and Shugart suggest that there is a risk of conflict between the companies. Unfortunately, we were unable to assess that risk based on our present information. However, to reduce the risk, it may be worthwhile to reiterate our expectation that Quantum will not rely on non-public Shugart/Xerox technical or non-technical information. The Shugart/Xerox confidential information that was entrusted to individuals who are now Quantum Corporation employees includes, without limitation, current and projected cost information, pricing plans, detailed technical design data (including negative know-how), market forecasts, production volume projections, special terms and conditions offered or proposed for customers, and information concerning pending and proposed patent applications.

In short, we believe that the nonconfidential meeting we had on March 7 at Quantum's offices was mutually beneficial. Your representations that Quantum Corporation intends to respect Shugart's and Xerox' proprietary rights were comforting. Moreover, our discussions with Messers. McCoy, Brown, Medley, Harrison and Daniels of the Quantum staff left us with the clear impression that they understand their serious continuing obligation to respect the confidentiality of the technical and non-technical tradescrets with which they were entrusted while employed by Shugart/Xerox.

XEROX

If we can do anything to further assist you and Quantum in safeguarding the Shugart/Xerox confidential information Quantum employees possess, please let us know.

Very truly yours,

Thomas M. Webster
Patent Attorney

TMW:skq

c: J. Bochnowski
B. Mulherin