A BRIEF HISTORY OF QUANTUM DESIGN'S PRODUCTS
7/25/00

I. INTRODUCTION OF TALK – TITLE SLIDE **VG – 1**

A. History Of Our Products

1. Technical aspects of the products
2. Business history of the products

B. How Does One Select A Product? **VG – 2**

1. Will people want to buy it? How many?
2. Can we sell it for a reasonable price?
3. Can we build it for a reasonable price?
4. Can we afford to develop it? To not develop it?

II. FIRST MPMS – The MARK I

A. Deciding To Build The MPMS **VG – 3**

1. Marketing survey – called my friends
2. Knew the market was about 6 units per year
3. At $100K each => $600K/year => $150K/man-year
4. Product encounter of the Second Kind

B. Developing The Mark I - Early Design Issues **VG – 4**

1. Ceramic coil form – helium cooled
2. Commercial Silicon-Copper tubing
3. Canvas-phenolic magnet form
4. Manganin heater wire
5. Yellow mylar tape

C. Materials Selection

1. Curie Law paramagnetism at low temperatures **VG - 5**
2. Temperature fluctuations => magnetic fluctuations

D. Early Measurement Results – 2:00am

1. Basic Design **VG – 6**
2. Initial measurements at zero field looked good
3. Put 1 Tesla in the magnet – noise was hideous
4. Noise level 1000 times above our specification
5. Finally used head phones – boiling water
6. Helium bubbles – diamagnetic bubbles

E. **Subsequent Measurement Results**

1. Silicon copper – paramagnetic at low temperatures
2. Canvas-phenolic coil form – paramagnetic at low temperatures
3. Manganin wire – highly paramagnetic
4. Yellow mylar tape – paramagnetic at low temperatures

III. FIRST PRODUCTS WE SHIPPED

A. **Model 1802 – First Product We Shipped** **VG – 7**

1. Temperature controller required for MPMS
2. Had to develop it anyway
3. Could generate some incremental revenue
4. Four thermometer channels – 16 bit convertor with ranging
5. Two Heater outputs – 250 mamps, 56 volts => 15 Watts
6. High precision thermometer/heater for cryogenic applications

B. **Chernobyl Alf**

1. Output control elements – FET devices
2. Heater failure mode – Full power to the load
3. Major design flaw => Complete recall
4. Replaced software and entire power output stage
   a. Failure protection – fail in power off mode
   b. Hardware voltage limit provided
   c. Allowed processor to monitor output current
5. Nickname for 1802 was Alfie
6. Early version became known as Chernobyl Alf

C. **THE FIRST MPMS – THE MARK I Slides**

1. Sold to Robert Shelton at Iowa State University
2. Installed in September 1984
3. HP-85 Computer
4. Fully automatic

IV. COMPETITION WITH SHE CORPORATION – 3 YEARS

A. **Redesigned MPMS To Compete** **VG – 8**

1. First QD SQUID control system
2. Increased magnetic field/improved magnetic field control
3. Improved temperature control
4. Extended range to lower temperatures
5. Increased amount of automation
6. Began developing additional options (low field)

B. SHE Variable Temperature Susceptometer (VTS) **VG – 9**

1. Price – $140,000
2. 5-Tesla magnetic field
3. Sub-2 Kelvin temperature control
4. Selling about 6 units/year
5. We knew its weaknesses

C. SHE Design – Why QD Won **VG - 10**

1. Inside The Vacuum Space
   a. SQUID Detection Coils
   b. Superconducting shield
   c. Heaters
   d. Thermometers
2. Heating Up Sample Chamber
   a. Thermal transfer via gas
   b. Thermometers distant from heater

D. QD Design – Back To VG – 6

1. Vacuum Sleeve was inviolate – metal-to-metal seals only
2. SQUID detection coils – Replaced in about 1 hour
3. Heaters & Thermometers – replaced by customer in 15 minutes
4. Thermometers & heaters are closely coupled

V. MPMS – THE EARLY YEARS

A. MPMS – The Introduction . . . **VG – 11**

1. Dec 1985 – Allen Goldman, Univ. of Minnesota
2. Feb 1986 – Brock University (Canada)
3. Mar 1986 – Dean Taylor, Los Alamos Nat. Lab
4. Jul 1986 – Bob Shelton, Iowa State

B. MPMS – The Precursor . . . **VG – 12**

1. Aug 1986 – SHE discontinues VTS
2. Sep 1986 – High-Tc materials are discovered
3. Mar 1987 – APS "Woodstock for Physicists"
4. Aug 1987 – Installing Serial # 11 & 12 at NTT in Japan
5. Dec 1987 – Shipped Serial #15
6. First Magnetization on a YBCO **VG – 13**

C. MPMS – The Flood . . . **VG – 14**

1. Jan – Mar 1988 – Shipped 11 units
   a. Half of these went to Japan
   b. First shipments > one/month
2. Apr – Jun 1987 – Shipped about 15 units
3. Apr – Jun 1987 – Accepted >$4M in orders
4. Delivery schedule went to over 15 months

D. The QD Business Plan – Dave Cox **VG – 15**

1. Start a company
2. Develop a really nice instrument
3. Pray for a miracle

VI. THE PHYSICAL PROPERTY MEASUREMENT SYSTEM (PPMS)

A. MPMS Developments **VG – 16**

1. Transverse Axis Measurement
2. AC Option: 0.1 Hz to 1000 Hz
3. 800 Kelvin Oven
4. Extended Dynamic Range

B. What Do We Do Now? **VG – 17**

1. MPMS Is An Established Product
2. Annual Revenues > $5M
3. Some Government (SBIR) Research
4. 1988 – Formed Quantum Magnetics

C. Competition

1. Lakeshore – Based in Ohio **VG – 18**
2. Hoxan – Japanese Company
3. CCL – British Company
4. Metronique – French Company

D. Our Next Development Project

1. Surveyed Existing MPMS Customers
2. Temperature Control
3. Magnetic Field Control
4. More Automation

E. Where's The SQUID? **VG – 19**

1. Precision Temperature Controlled Sample Chamber
2. Precision Magnetic Field Control
3. Quantum Design – Defined By MPMS
4. Customers Expect Complete Solutions

F. What's A PPMS?

1. Independent Components **VG – 20**
2. Probe – Magnet & Sample Chamber **VG – 21**
3. Sample Chamber – Accept various inserts **VG – 22**
4. Puck Design **VG – 23**
5. Various Inserts **VG – 24**

G. PPMS MEASUREMENT FAMILY **VG – 25**

1. Transverse Magnet Configuration
2. AC/DC Magnetometer System
   a. First Shipment – 1992
   b. Competition with Lakeshore Cryotronics
3. AC Transport Option
   a. AC Resistivity
   b. 4-Terminal I/V Measurements
   c. 5-Terminal Hall Effect Measurements
   d. Thin Film Critical Current Measurements
4. Low Field Option
5. Magnetic Fields to 14 Tesla
6. Heat Capacity Measurements
   a. Dewar Configuration **VG – 26**
   b. Heat Capacity Puck **VG – 27**
7. Rotator Capability – Anisotropy Measurements **VG – 28**
8. Torque Magnetometer – Magnetic Anisotropy **VG – 29**
9. Low Temperature Insert (0.5 Kelvin)
   a. He-3 System **VG – 30**
   b. 0.5 Kelvin Insert **VG – 31**

VII. PPMS AS A PRODUCT

A. Has It Been Successful? Yes!!

1. Widely Accepted
2. Fueled Significant Growth
3. Becoming A Standard Platform
4. Growing List of Users & Applications

B. QD Continues To Develop New Options

1. Thermal Transport Option
2. To Be Announced

VIII. MOST RECENT PRODUCT DEVELOPMENTS

A. Conductus X-Mag SQUID Magnetometer **VG - 32**

1. Lost about $1M in Japanese orders
2. Only six systems were actually sold
3. System is now completely off the market

B. MPMS-XL **VG – 33**

1. New Flagship Product **VG – 34**
2. Improved Temperature Control Below 4 Kelvin
    a. Continuous Low Temperature
    b. Temperature Sweep
    c. Improved Thermometry
3. Reciprocating Sample Option
    a. Improved sensitivity
    b. Faster Measurements

C. MPMS/PPMS HELIUM CONSUMPTION **VG - 35**

1. Operating Cost (U.S.) - $10K/year
2. Operating Cost (Japan/Europe) - $20-$40K/year
3. Limits the market for the instruments

D. EverCool Eliminates Liquid Helium Consumption **VG -36**

1. Cryocoolers Now Reach 3K
2. High Heat Capacity in Second Stage
3. Cooling Power Adequate to Recondense Liquid Helium
4. Sumitomo Coolers – 1.5 Watts at 4.2K
5. First MPMS EverCool shipped in May 1999
6. Orders have been strong
7. Primary market is Japan
8. MPMS EverCool Introduced In 1999

.IX. CRYOGENIC PRODUCTS UNDER DEVELOPMENT

A. **EverCool For PPMS Is Under Development**

1. First PPMS EverCool To Ship December 2000
2. Expect Excellent Product Acceptance

B. **DynaCool PPMS** **VG - 37**

1. No Liquid Helium
2. First Demonstrated in March 1998
3. Product Development Delayed

X. BIOTECHNOLOGY PRODUCTS **VG – 38**

A. **Magnetic Particles**

1. Widely used in biological processes
2. Mostly used for separation
3. Particles are readily available

B. **QD Magnetic Assay Reader (MAR)**

1. Can quantify the number of particles
2. Related to number of molecules
3.