

Serial Number 09/606,104
Filing Date 9 June 2000
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1 Attorney Docket No. 78065

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3 WEAPONS AND LAUNCHER TEST SET (WALTS)

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6 STATEMENT OF GOVERNMENT INTEREST

7 The invention described herein may be manufactured and used
8 by or for the Government of the United States of America for
9 Governmental purposes without the payment of any royalties
10 thereon or therefor.
11

12 BACKGROUND OF THE INVENTION

13 (1) Field of the Invention

14 The invention relates to the field of weapons test equipment
15 and in particular to testing and monitoring of combat, weapon and
16 launch transient signals for submarine-launched weapons.

17 (2) Description of the Prior Art

18 Shipboard and submarine-launched weapons use data and
19 electrical communications with the ship's systems to provide
20 location, navigation, targeting and fuzing/yield data. In order
21 for these weapons to operate properly it is necessary to test all
22 data and electrical interface signals and to test internal weapon
23 guidance and operating systems. Special test equipment has been

1 designed to monitor combat, weapon and launched transient signals
2 and are necessary to certify launched system readiness. The MK
3 617 Launched System Test Set (LSTS), Quick Look Launcher Test Set
4 (QLLTS), and the MK 621 Torpedo Tube Instrumentation (TTI) have
5 been used for over thirty years to perform this certification.
6 Certain disadvantages of the current equipment are becoming
7 pronounced. As a result of time and heavy usage, these special
8 test equipment systems are experiencing numerous component
9 failures. Many of the components are antiquated and cannot be
10 fixed or replaced. Custom repairs are possible, but are both
11 expensive and time consuming. The recorders on the special test
12 equipment systems are heavy and bulky. As a result, the test
13 systems are unwieldy and difficult to hand-carry, especially
14 passing through relatively small submarine hatches. Further, the
15 data traces generated with these recorders are imprinted on
16 expensive, light sensitive paper, which deteriorates over time,
17 thereby destroying any record of the weapons launch. Also,
18 analysis and reporting on launch data traces with existing test
19 systems are not immediately available. Instead, the data traces
20 from recorders must be manually reduced and analyzed, a time
21 intensive process subject to human error and inconsistent
22 interpretation. Along with the aging test equipment, weapons and
23 launching systems are becoming increasingly complex. A need

1 exists for test systems to flexibly and accurately monitor
2 additional signals, such as the new signals driven by recent
3 Harpoon, Tomahawk, and Seawolf weapons requirements.

4
5 SUMMARY OF THE INVENTION

6 Accordingly, it is an object of the invention to provide a
7 ruggedized, portable data acquisition system having a lightweight
8 and compact form suitable for hand-carrying in confined shipboard
9 spaces.

10 It is another object of the invention to provide a portable
11 data acquisition system which produces an immediate readout and
12 interpretations of data traces.

13 It is yet another object of the invention to provide a
14 portable data acquisition system which is fabricated using off-
15 the-shelf, commercially available notebook computers.

16 It is a further object of the invention to provide a
17 portable data acquisition system which can be reprogrammed to
18 monitor different or new signals as needed.

19 The invention is a portable data acquisition system
20 comprising a portable computer using PCMCIA data acquisition card
21 (DAQCard 1200), rugged four slot chassis (SCXI 1000),
22 multiplexing amplifier (SCXI 1102C), four channel isolation
23 amplifier with excitation (SCXI 1121), eight channel isolation

1 amplifier (SCXI 1120) and associated terminal blocks and
2 interface cables. All components are housed in a shock resilient
3 and weather tight case. Power is supplied to the case through a
4 standard AC outlet and is distributed to the PC and signal-
5 conditioning unit. The portable computer is located in the upper
6 half of the case, while the signal-conditioning unit is located
7 in the bottom portion. Cable connections are located on a
8 removable panel on one side of the case. The sensor cable mates
9 directly to existing MK 617 ancillary equipment such as the
10 Pressure Velocity Displacement (PVD) assembly and related
11 components, B-B and BBY's etc. In addition, a new sensor cable
12 is included. This cable has additional conductors which enable
13 all ADCAP, Harpoon, and Tomahawk signals to be received without
14 the use of adapters. In addition, the sensor cable can also be
15 connected to the MK 617; PVD Housing Assembly, guidance wire
16 cable, fire solenoid inductive pick-up coil, and BBY adapter. An
17 additional cable routes Turbine Pump Ejection System (TPES) rpm
18 signal to the portable data acquisition system. The system
19 includes software written in LabVIEW for Windows™, a visual
20 programming language development by National Instruments Company.
21 A variety of tasks are presented by a main menu which include
22 data acquisition for the MK48/ADCAP or Harpoon/Tomahawk of
23 signals post processing calibration, and real-time signal display

1 for trouble shooting. Weapon specific signals are acquired and
2 displayed along with pertinent signal event timing (automatically
3 computed).

4 5 BRIEF DESCRIPTION OF THE DRAWINGS

6 The foregoing objects and other advantages of the present
7 invention will be more fully understood from the following
8 detailed description and reference to the appended drawings
9 wherein:

10 FIG. 1 is an exploded perspective view of the overall
11 portable data acquisition system;

12 FIGS. 2A and 2B are perspective view of prior art devices;

13 FIGS. 3A and 3B are schematic representations of a torpedo
14 component and signal interface with the portable data acquisition
15 system;

16 FIG. 4 is a typical data trace for a MK 48 ADCAP Launch;

17 FIG. 5 is a typical data trace for a Tomahawk Launch; and

18 FIG. 6 is a typical data trace for a shape launch.
19

20 DESCRIPTION OF THE PREFERRED EMBODIMENTS

21 Referring now to FIG. 1, the overall portable data
22 acquisition system, designated generally by the reference numeral
23 10, is shown with its major components. The portable data

1 acquisition system 10 is operated by a portable computer 12
2 which, along with the other system components, is packaged in the
3 protective case 14, and is protected during transport or non-use
4 by the protective lid 16. The protective case 14 is divided
5 internally by a removable panel 18 between the upper section,
6 containing the portable computer 12, and the lower section
7 containing signal conditioning components and cable interface.
8 The shock mount and portable computer 12 hold-down tray is
9 mounted to the panel 18, various connectors for the AC power
10 adapter 24, which provides DC power to the portable computer, and
11 the PCMCIA card 20 with the connecting interface cable 22. The
12 removable panel 18 also has switches and controls to power up an
13 AC outlet and the lower section equipment. This equipment
14 includes the signal-conditioning unit 26 which is mounted on a
15 shock isolation plate 28 which is fastened to the bottom of the
16 case. The signal-conditioning unit 26 has a plurality of signal
17 processing modules having for sub-components, the 32-channel
18 multiplexer 31, the 4-channel amplifier with excitation 32, the
19 signal conditioning module 34, and the 8-channel isolation
20 amplifier 36. A ribbon cable 31 connects the multiplexer to the
21 data connector on the removable panel 18. Terminal block
22 connectors are used to interconnect the 4-channel amplifier 32,
23 the signal conditioning module 34, and the 8-channel isolation

1 amplifier 36 to the external data cable connectors 38 on the side
2 of the case 14. AC power is provided by the power chord 40. In
3 the preferred embodiment, the portable computer 12 is a personal
4 notebook computer. Any Pentium™ 75 MHz or greater may be used,
5 however a ruggedized computer such as the Panasonic CF25™, will
6 provide additional longevity.

7 FIG. 2 shows existing ancillary MK 617 components 40 and 42
8 which can be used with the new portable data acquisition system
9 10. FIG. 3 is a schematic showing the aft end of a torpedo 44 in
10 firing position in a torpedo tube. The portable data acquisition
11 system 10 (not shown) is attached to connector 54 which connects
12 by sensor cable 56 to the various signal sources. Ancillary
13 components, shown for reference, are the wet side pressure
14 transducer assembly 46, the dry side pressure transducer assembly
15 64, the PVD housing assembly 68 and the PV pistol 70. On the top
16 side of the tube, the firing solenoid 50 and the solenoid pick-up
17 coil 48 are shown. The portable data acquisition system is
18 connected to these various components by the various connectors,
19 the firing solenoid leg 52, the torpedo guidance leg 58, the Post
20 Ordalt 15617 guidance wire connector 60, the weapon and fire
21 control signal sensor leg 66, connecting to the B-B or BB-Y
22 connectors 82, and the pressure velocity displacement (PVD) leg
23 62.

1 The acquisition and post processing software was written in
2 "LabVIEW for Windows™", a visual programming language developed
3 by National Instruments. When run, the Main Menu is displayed.
4 A variety of tasks are presented which range from:

- 5 • Acquire Data-Acquires processes Mk48/ADCAP, or Tomahawk
6 data. When the acquisition routine is run scaled, signal
7 voltages, frequencies, and various timing parameters
8 required for torpedo tube certification are automatically
9 displayed. The data collected is stored in a file
10 consisting of ASCZZ text followed by binary signal data. The
11 ASCII text header contain: Various run and test
12 configurations, timing results, Channel Calibrations.
13 Results for each run are automatically logged for future
14 reference. The below table summarizes the signals acquired
15 by the system for various weapon systems.

16 SIGNAL ACQUISITION

17 WALTS is currently capable of acquiring the following
18 signals:

FIRE CONTROL	WEAPON SIGNALS	WEAPON	LAUNCH TRANSIENTS
IMPULSE RETURN	FIRE ORDER		FIRING SOLENOID
IDENT PWR	MAIN MOTOR START		BRCH DOOR PRES.
SERVICE POWER	GUIDANCE WIRE	Mk 48/ADCAP	TORPEDO VEL.
+ MISSILE IDENT PWR	ACABLE SEVER		TORPEDO ACCEL.
	28VDC POWER		TORPEDO DISPL.
	MONITOR		TPES PUMP SPEED
	IDENT BIT 1		
	BOOSTER SAFED CMD		
	CMGS REPROGRAM CMD		
	REM ABORT CMD		
	PCM INSTRUMENTATION	TOMAHAWK	
	+BOOSTER SAFED MON.		
	+SIMULATOR PRESENT		
	+DC MON/RESET PWR		
	+INTENT TO LAUNCH		
	+MISSILE ENABLED		
	+BOOSTER ARMED MON.		
	+MISSILE BUS MON		
	+BATTERY HEATER PWR		
	MGU SEEKER/HEATER		
	MISSILE PRESENT		
	CAPSULE SAFE CMD		
	TELEMETRY ON/OFF		
	STB STEEROFF	+HARPOON	
	PORT STEEROFF		
	AN/BSY-2 FLOOD		
	AN/BSY-2 ABORT		
NOTE: + INDICATES THE SIGNAL ALSO APPLIES FOR HARPOON WEAPONS			

- Reprocess Data-Looks for archived data and allows new calibrations to be applied to the raw data set. This data can be processed and displayed.
- Calibrate-Captures and processes calibration data of transducers and other signals (pressure transducer, tachometers, etc.). Calibrates transducers, tachometers, and voltage sources. Obtains correct relationship between the raw signal (volts) and engineering units (psi, ft/s).
- Transfer Data to EXCEL™, Transfers the following timing parameters to EXCEL™ spreadsheet:
 - Firing Volts to Impulse Return
 - Weapon Launch Switchboard Switch Box Time
 - Impulse return to Main Motor Start
 - Main Motor Start Duration
 - Firing Solenoid to End of Service Power
 - Peak Tube Door Pressure
 - Ram cycle Time (for Ram Pump Ejection System)
 - Torpedo exit velocity
 - Peak torpedo acceleration

And the peak signal frequencies of the following signal:

- Firing Volts

- 1 - Impulse Return
- 2 - Main Motor Start
- 3 - Guidance Wire

4 FIG. 4 displays a typical post processing screen 72 for
5 either MK 48 or ADCAP weapons. The data acquired is processed
6 and plotted in real time. After the acquisition is complete,
7 cursors can be brought up to track signals and zoom-in on any
8 part of any of the captured signals. Based on the current sample
9 rate (800 Hz), one could zoom-in on any of the plots, and view
10 data to within 1.25ms resolution.

11 Timing parameters 74 are automatically computed and
12 displayed as shown on the right side of the screen. The
13 "Indicators" box displays green dots for every signal which falls
14 within acceptable voltage range per specifications. "Breach Door
15 Parameters" box 78 displays: TIME@STRT (time at which breach door
16 pressure starts to rise), TIME@PEAK (time at which peak door
17 pressure occurs), MAX PRES (maximum breach door pressure), DT
18 (time difference between TIME@PEAK and TIME@STRT, and TIME@15PSI
19 (the time at which 15 psi occurs). The small chart 80 on the
20 bottom right indicates an estimate of peak acceleration that
21 would be achieved if a Mk48/ADCAP was launched.

22 Raw data files for each run are automatically stored on the
23 hard drive in a path created by the information entered by the

1 user about the specific platform. Data is therefore stored in a
2 directory dictated by Hull No.\Date\Weapon\Tube No.\Run No. which
3 the user could post process at a later date. The raw data file
4 consists of an ASCII text header containing the run summary and
5 channel calibrations followed by binary multiplexed channel data,
6 thereby minimizing storage requirements.

7 The portable data acquisition system 10 automatically determines
8 and stores the followings parameters:

9 Timing Parameters:

- 10 - Fire Order to Impulse Return
- 11 - Weapon Launch Switchboard Switch Box Time
- 12 - Firing Solenoid to End of Service Power
- 13 - Impulse Return to Main Motor Start
- 14 - Main Motor Start Duration
- 15 - Unrestrained Weapon Time
- 16 -15 psig Indication

17 Other Parameters:

- 18 - Torpedo exit velocity
- 19 - Peak torpedo acceleration
- 20 - Peak tube door pressure
- 21 - Estimate of Peak Torpedo Acceleration (based on
22 breach door pressure correlation)

23 and automatically determines the peak signal frequencies of:

- 1 - Impulse Return
- 2 - Main Motor Start
- 3 - Guidance Wire

4 The above parameters obtained with previous test sets
5 (QLLTS, Mk617, TTI) had to be manually measured with calibrated
6 scales and interpreted. The portable acquisition system reduces
7 these parameters automatically with the following advantages:

- 8 - No calibrated scales required
- 9 - Immediate results not subject to interpretation
- 10 - Eliminates manual processing minimizing human error
- 11 - Provides consistent, accurate results in a fraction
12 of time required Mk617, QLLTS, TTI.

13 The features and advantages of the invention are numerous.
14 Data acquisition/post processing can be performed in a user-
15 friendly PC Window™ environment. In the present invention data
16 reduction/post processing is fully automated. Engineering plots
17 are automatically generated displaying the signal-time history,
18 peak voltages, frequencies, and critical signal timing
19 parameters. This display eliminates the laborious and time-
20 consuming task of manually determining peak data values from
21 calibrated scale strip charts and provides fast, consistent, and
22 accurate results in a fraction of time required by either Mk 617,
23 TTI or QLLTS as well as minimizing human error and

1 TTI or QLLTS as well as minimizing human error and
2 inconsistencies due to interpretation while dramatically speed up
3 data analysis and reporting. Raw and reduced data is
4 automatically stored in magnetic media in appropriate directories
5 for easy access/retrieval and can be readily transferred to any
6 other PC for dissemination or further post processing. The
7 present invention can acquire up to 44 channels of data, a
8 significant increase over the LSTS. The LSTS only has 18
9 channels, which is more than either TTI or QLLTS systems. Data
10 is always readily available if needed for further processing.

11 The displayed results can be printed on plain paper, thereby
12 eliminating the use of expensive, unstable, light sensitive paper
13 used by existing LSTS, TTI, and QLLTS systems. WALTS can be
14 operated by a commercial off-the-shelf system such as any
15 Pentium™ 75 MHz notebook PC with PCMCIA Type II slots and
16 "Windows 95™" operating system with a minimum of 24 megabytes of
17 RAM. Down time due to PC failures is minimized since many
18 suitable substitutes exist. As nearly all of the electrical
19 parts are Commercial-off-the-shelf (COTS) component availability
20 is improved and system costs are minimized.

21 Further, the components of the present invention are modular
22 and easily replaced if damaged. The current system is 50%
23 smaller and lighter than the LSTS recorder, which it replaces.

1 In the present invention, the system channel count can be
2 expanded by adding another PCMCIA data acquisition card. The
3 WATS sensor cable contains additional conductors to anticipate
4 future Harpoon, Tomahawk and Seawolf requirements and are field
5 repairable with splash proof back-shells.

6 It will be understood that many additional changes in the
7 details, materials, steps and arrangement of parts, which have
8 been herein described and illustrated in order to explain the
9 nature of the invention, may be made by those skilled in the art
10 within the principle and scope of the invention.
11

1 Attorney Docket No. 78065

2
3 WEAPONS AND LAUNCHER TEST SET (WALTS)

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5
6 ABSTRACT OF THE DISCLOSURE

7 A portable data acquisition system for use in certifying
8 torpedo tube launched weapons is provided. The system includes a
9 portable computer using PCMCIA data acquisition card (DAQcard
10 1200), rugged four slot chassis (SCXI 1000), a 32 channel
11 multiplexing module (SCXI 1102c) four channel isolation amplifier
12 with excitation (SCXI 1121), eight channel isolation amplifier
13 (SCXI 1120) a custom signal conditioning module, and associated
14 terminal blocks and interface cables. All components are housed
15 in a shock resilient and weather tight protective case. Power is
16 supplied to the case through standard AC Outlet and is
17 distributed to the PC and signal-conditioning unit. The portable
18 computer is located in the upper section of the case, while the
19 signal-conditioning unit is located in the lower section. Cable
20 connections are located on a removable panel on one side of the
21 case. Ship's cables mate directly to these connectors. A new
22 torpedo interface cable provides additional conductors which
23 enables all Mk48/ADCAP, Harpoon, and Tomahawk signals without the

1 use of adapters. The system also includes processing software
2 which automates data acquisition, display and certification of a
3 torpedo tube.

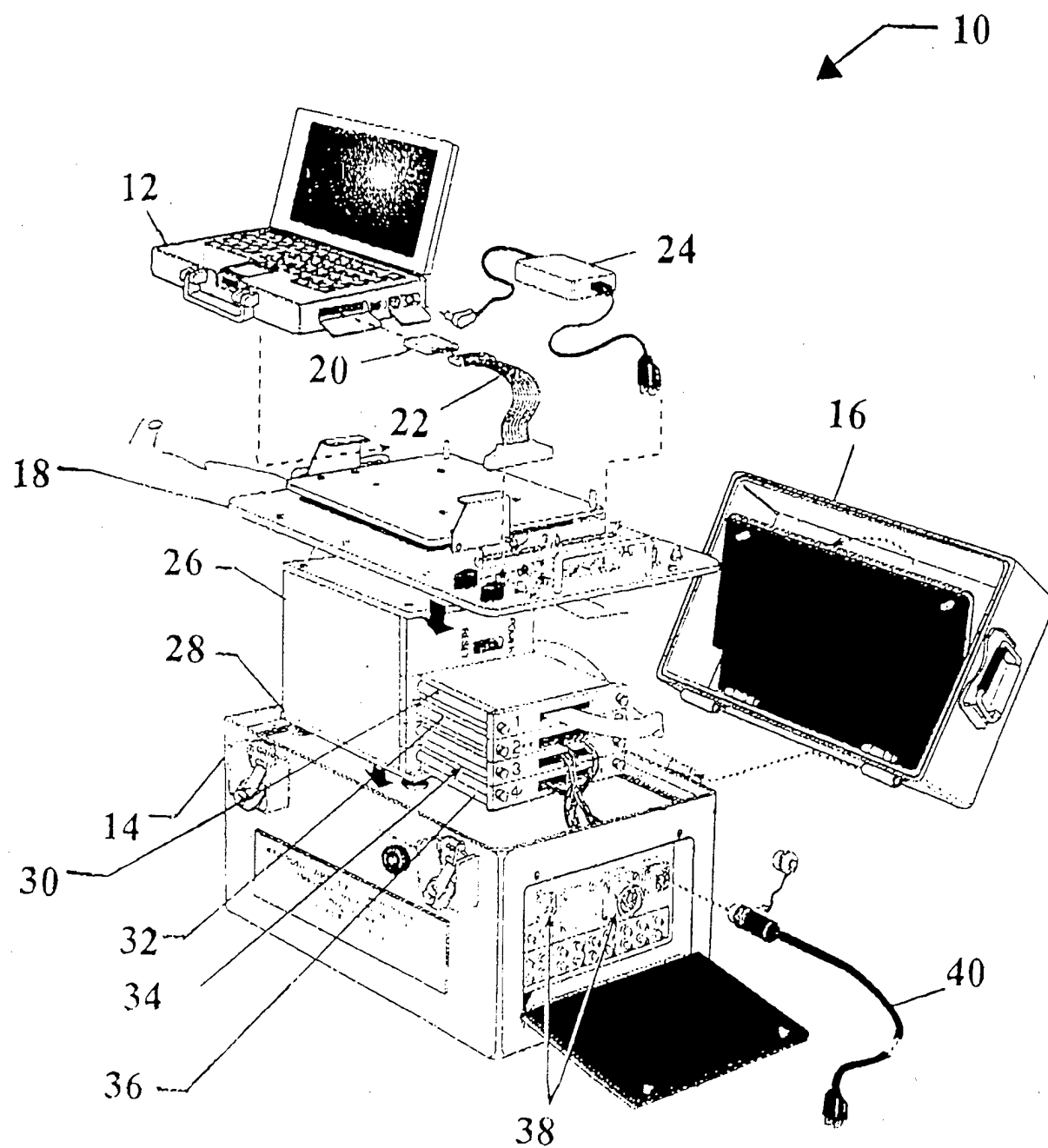


FIG. 1

FIG. 2A

PRIOR ART

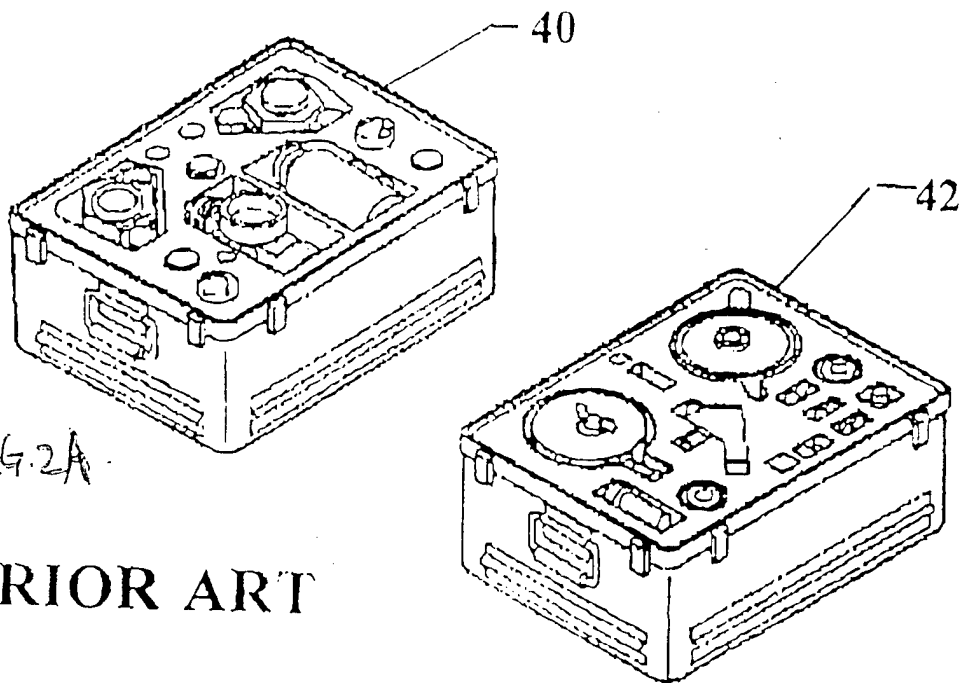


FIG. 2B

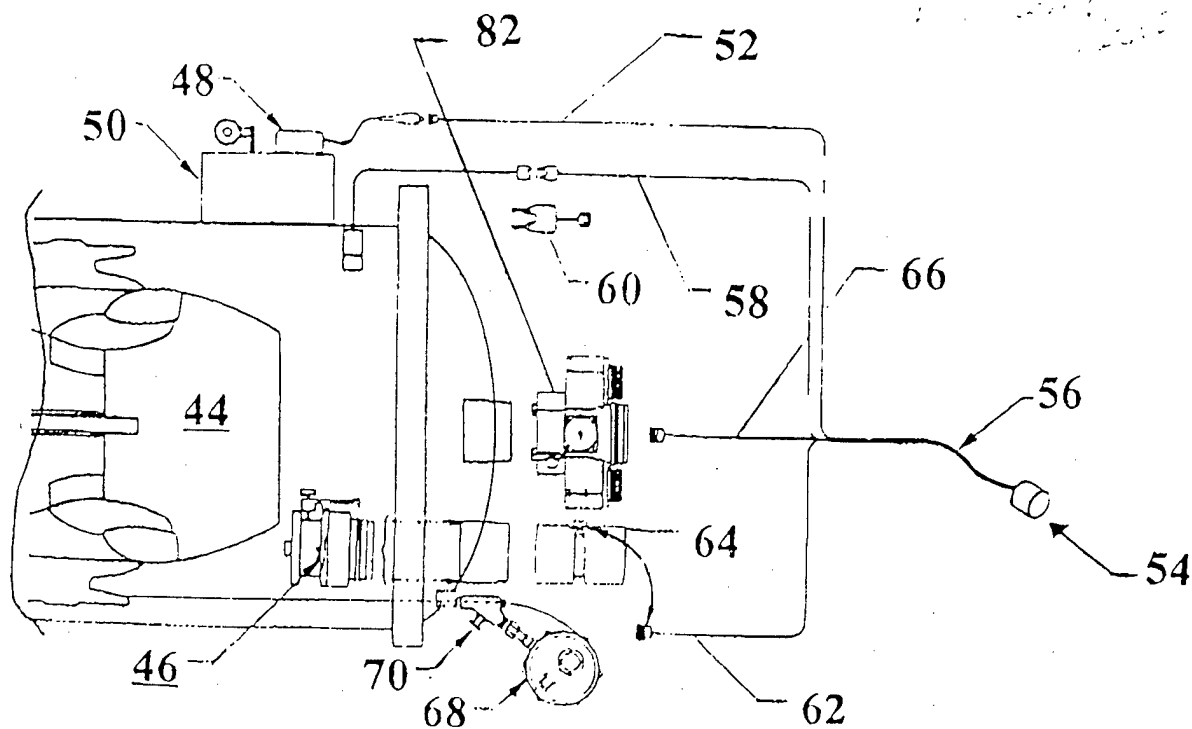


FIG. 3A

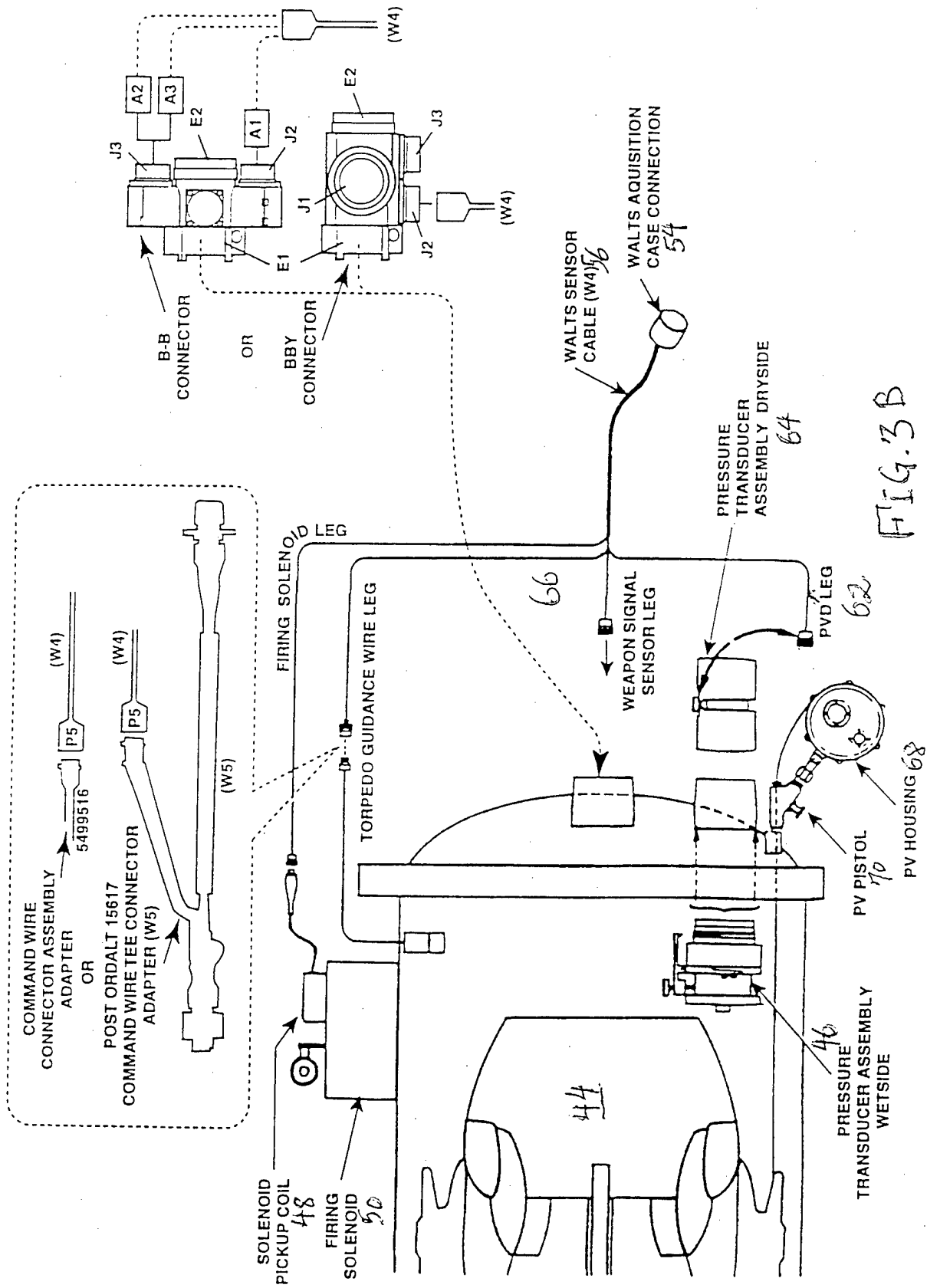


FIG. 3B

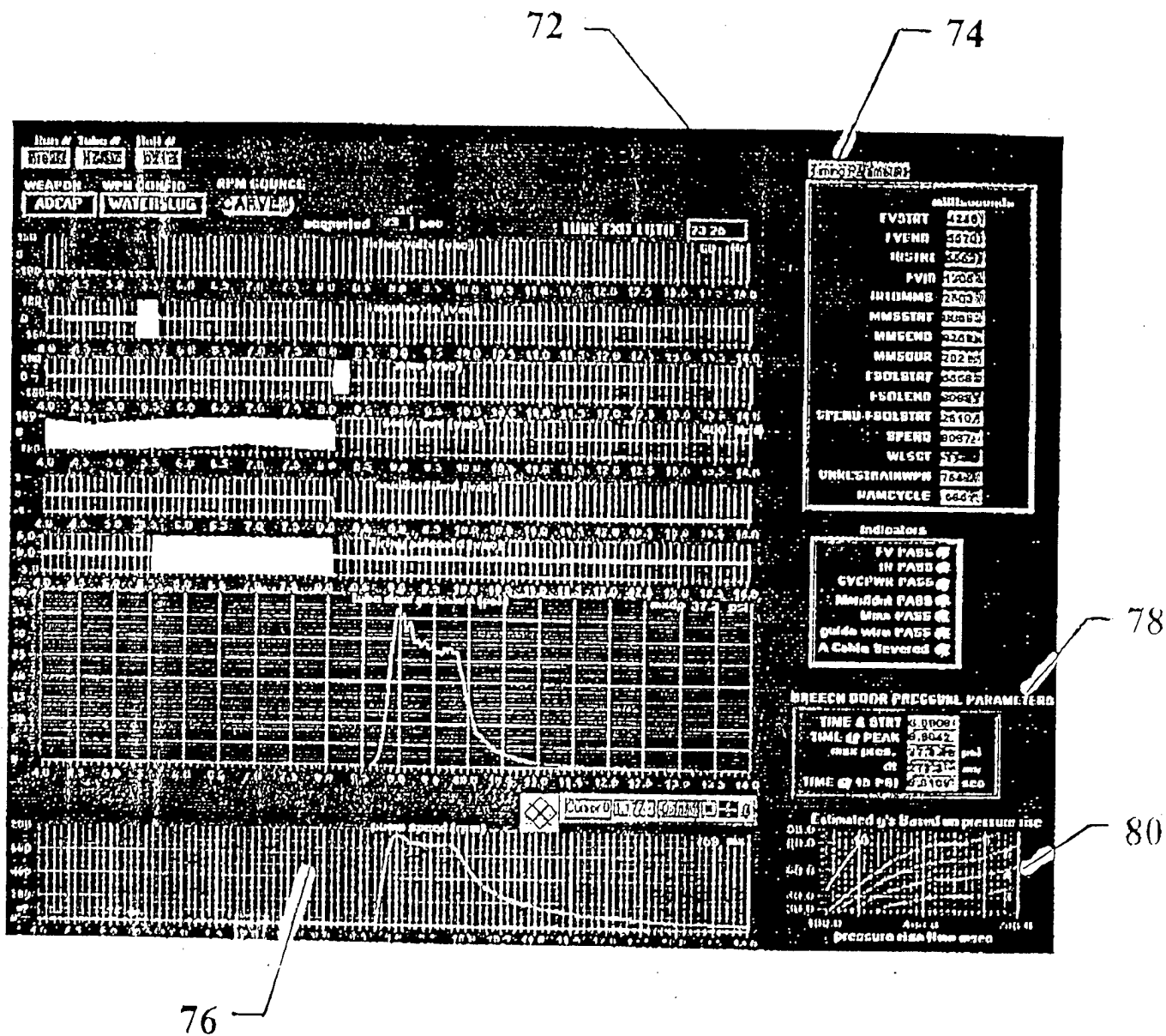


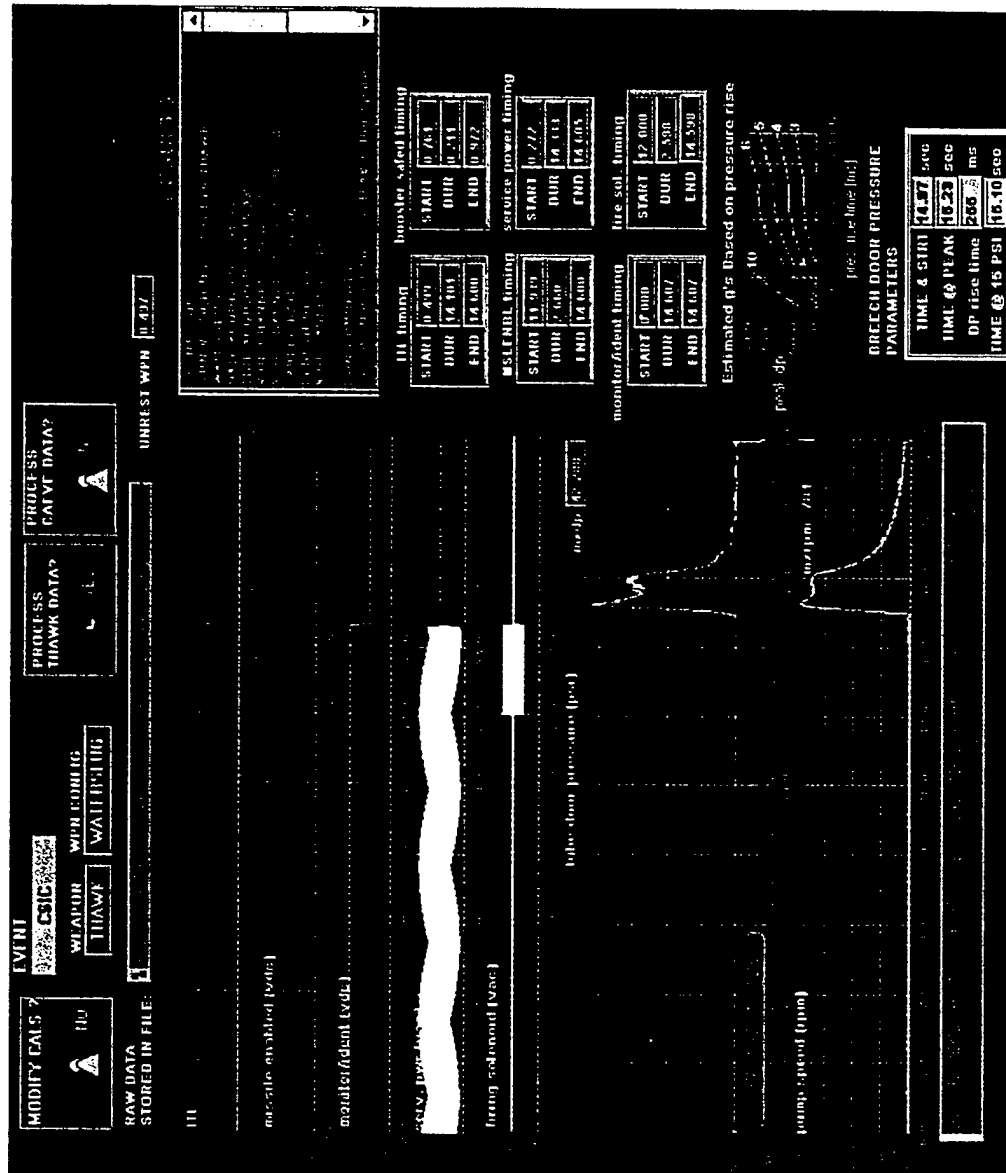
FIG. 4



Weapons and Launcher Test Set

WALTS

TOMAHAWK POST PROCESSING SCREEN



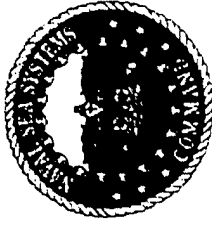
516.5

UNCLASSIFIED



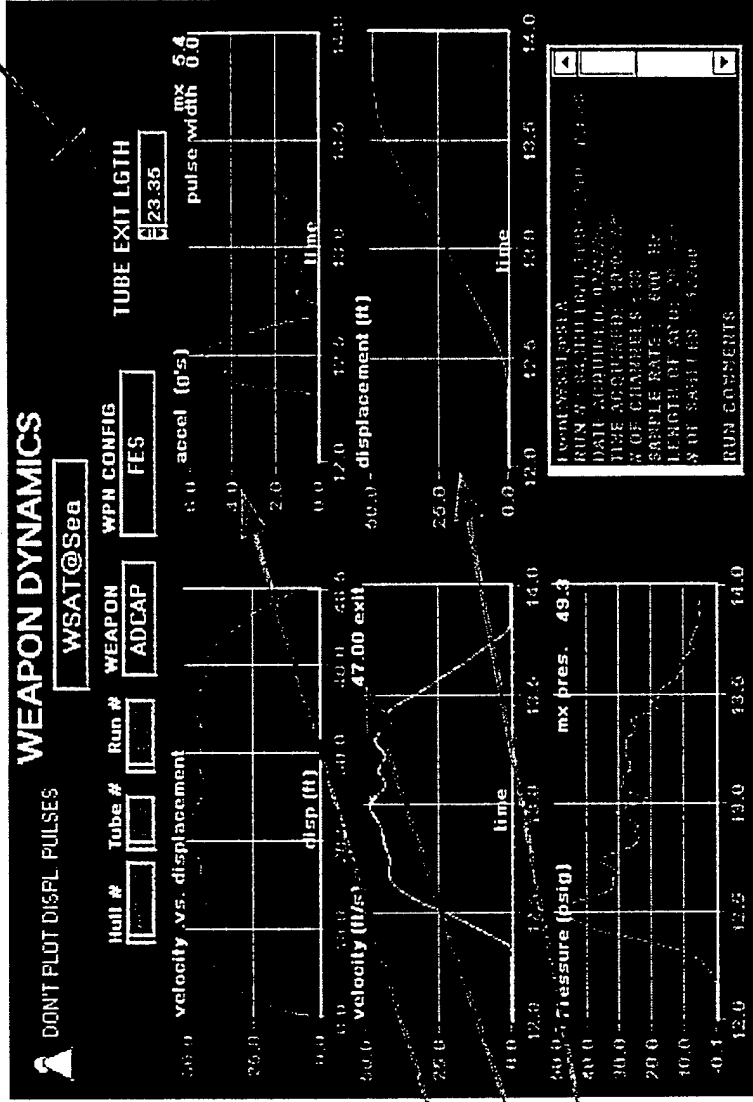
Weapons and Launcher Test Set

WALTS



- AUTOMATIC DATA REDUCTION:

PREDETERMINED
EXIT LENGTH



COMPUTED:
ACCELERATION CURVE
EXIT VELOCITY
DISPLACEMENT

Fig. 6