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NOTICE

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WEAPONS AND LAUNCHER TEST SET (WALTS)

STATEMENT OF GOVERNMENT INTEREST

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

BACKGROUND OF THE INVENTION

(1) Field of the Invention

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

(2) Description of the Prior Art

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

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

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

SUMMARY OF THE INVENTION

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

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

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

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

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

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

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

BRIEF DESCRIPTION OF THE DRAWINGS

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

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

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

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

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

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

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

DESCRIPTION OF THE PREFERRED EMBODIMENTS

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

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

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

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

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

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

SIGNAL ACQUISITION

WALTS is currently capable of acquiring the following 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

- Impulse Return

- Main Motor Start

- Guidance Wire

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

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

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

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

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

Timing Parameters:

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

Other Parameters:

- Torpedo exit velocity
- Peak torpedo acceleration
- Peak tube door pressure
- Estimate of Peak Torpedo Acceleration (based on breach door pressure correlation)

and automatically determines the peak signal frequencies of:

- Impulse Return
- Main Motor Start
- Guidance Wire

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

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

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

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

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

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

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

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

Attorney Docket No. 78065

WEAPONS AND LAUNCHER TEST SET (WALTS)

ABSTRACT OF THE DISCLOSURE

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

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

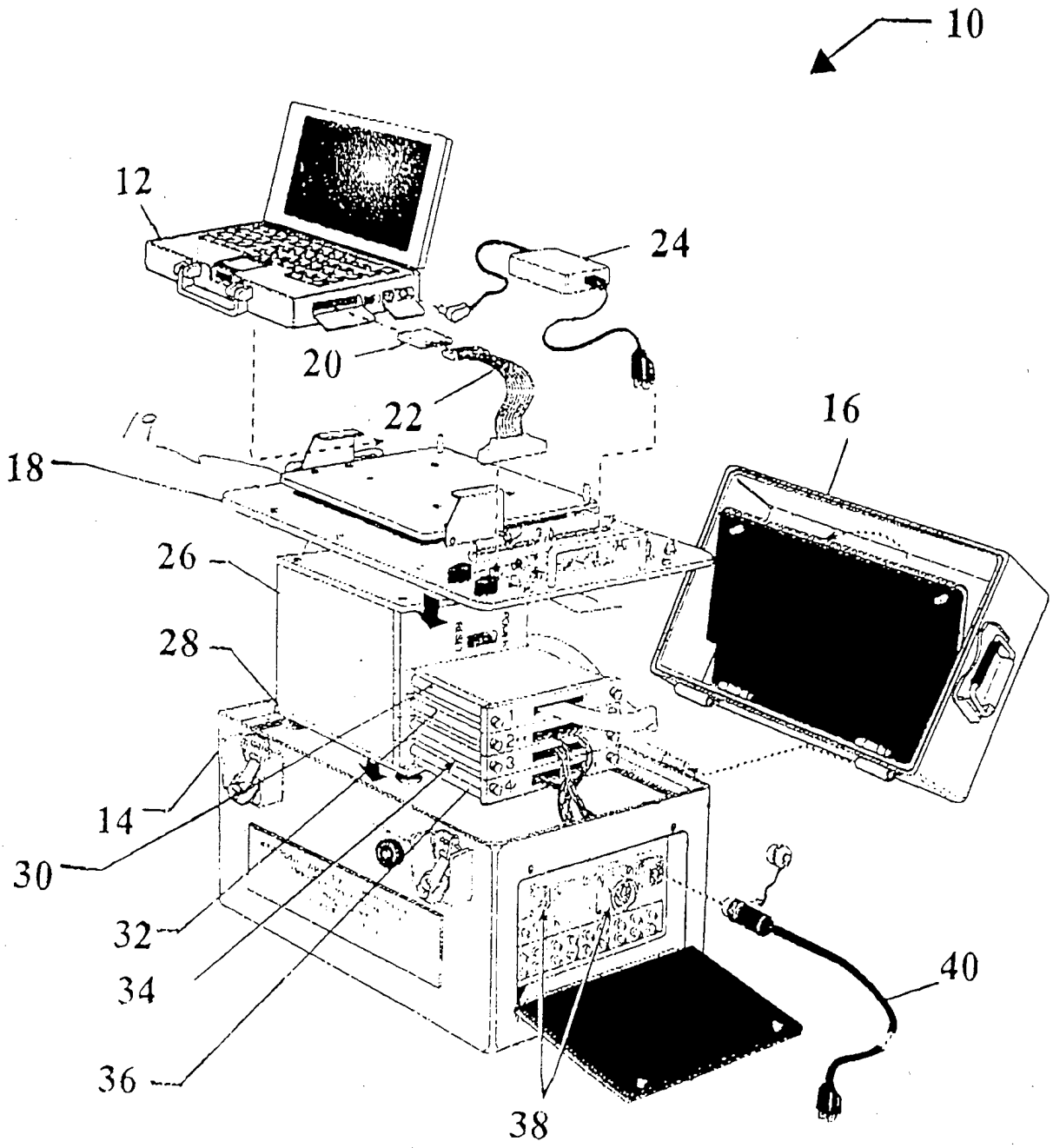


FIG. 1

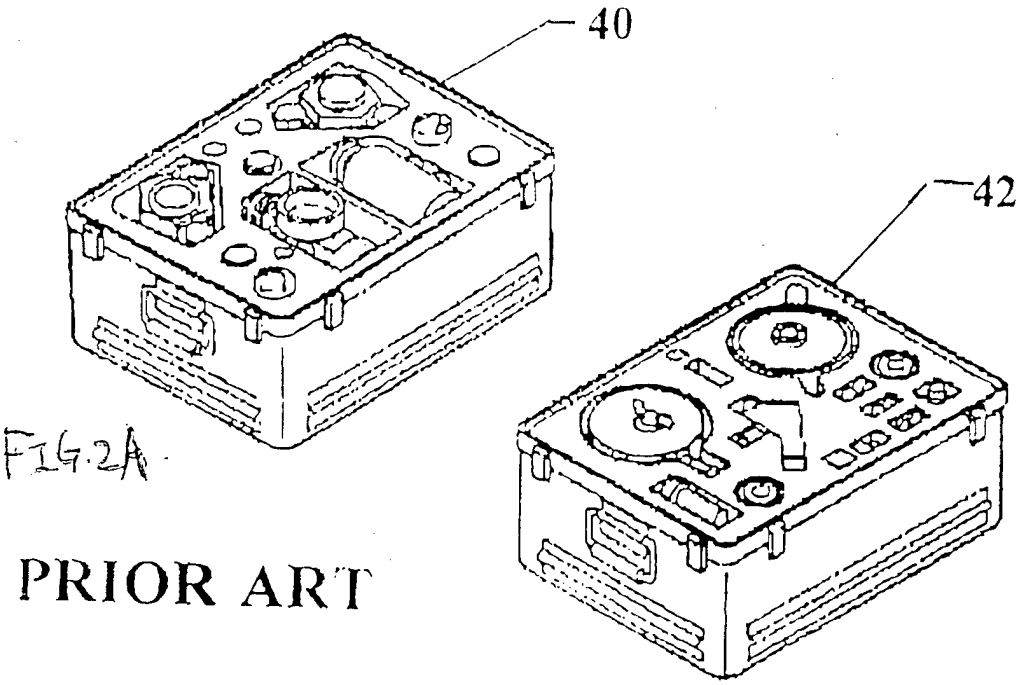


FIG. 2A

PRIOR ART

FIG. 2B

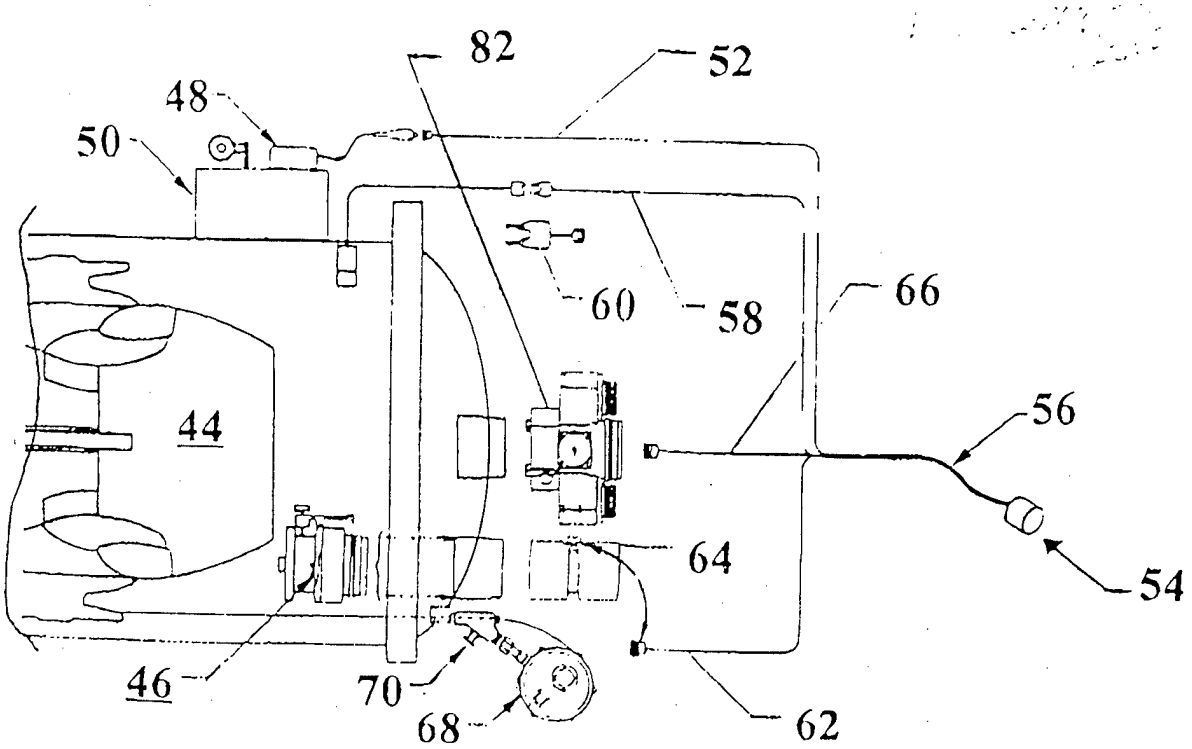


FIG. 3A

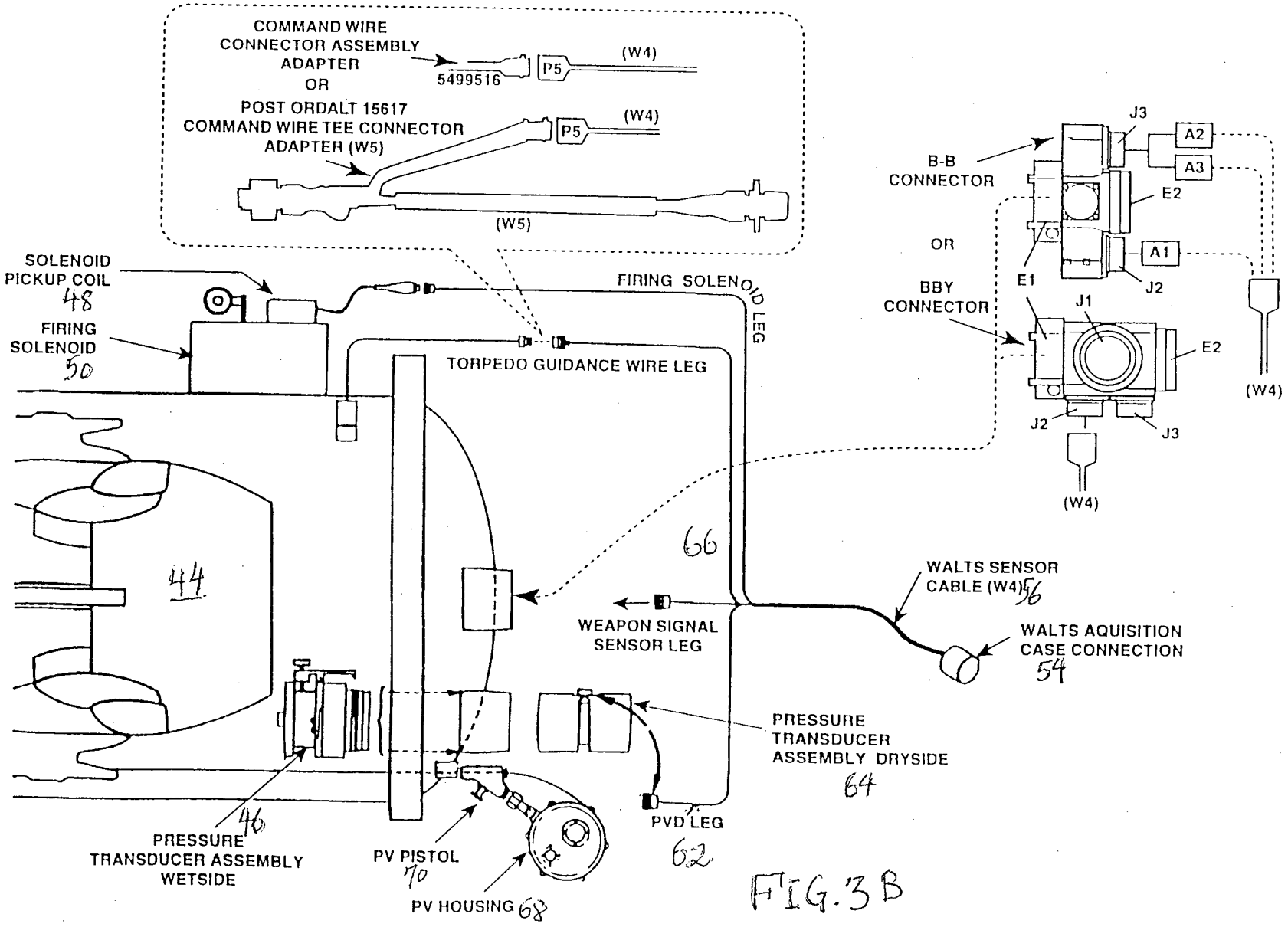

COMMAND WIRE
CONNECTOR ASSEMBLY
ADAPTER
OR
5499516
P5
(W4)
POST ORDALT 15617
COMMAND WIRE TEE CONNECTOR
ADAPTER (W5)
P5
(W4)
(W5)
B-B
CONNECTOR
OR
BBY
CONNECTOR
J3
A2
A3
E2
A1
E1
J2
J1
E2
J2
J3
(W4)
(W4)
SOLENOID
PICKUP COIL
48
FIRING
SOLENOID
50
FIRING SOLENOID LEG
TORPEDO GUIDANCE WIRE LEG
44
66
WEAPON SIGNAL
SENSOR LEG
WALTS SENSOR
CABLE (W4) 56
WALTS AQUISITION
CASE CONNECTION
54
PRESSURE
TRANSDUCER
ASSEMBLY DRYSIDE
64
PRESSURE
TRANSDUCER ASSEMBLY
WETSIDE
46
PV PISTOL
70
PV HOUSING 68
PVD LEG
62

FIG. 3B

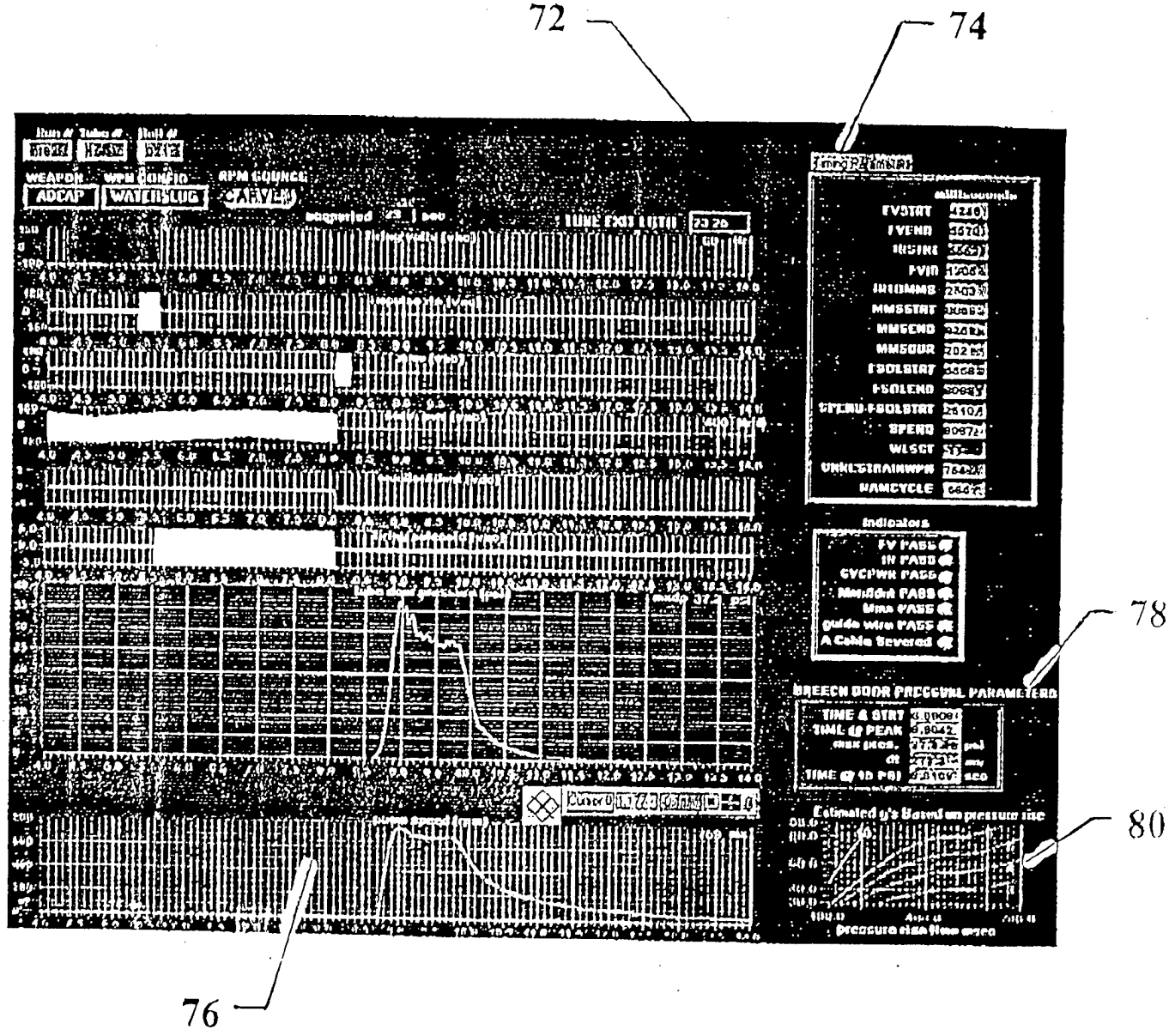
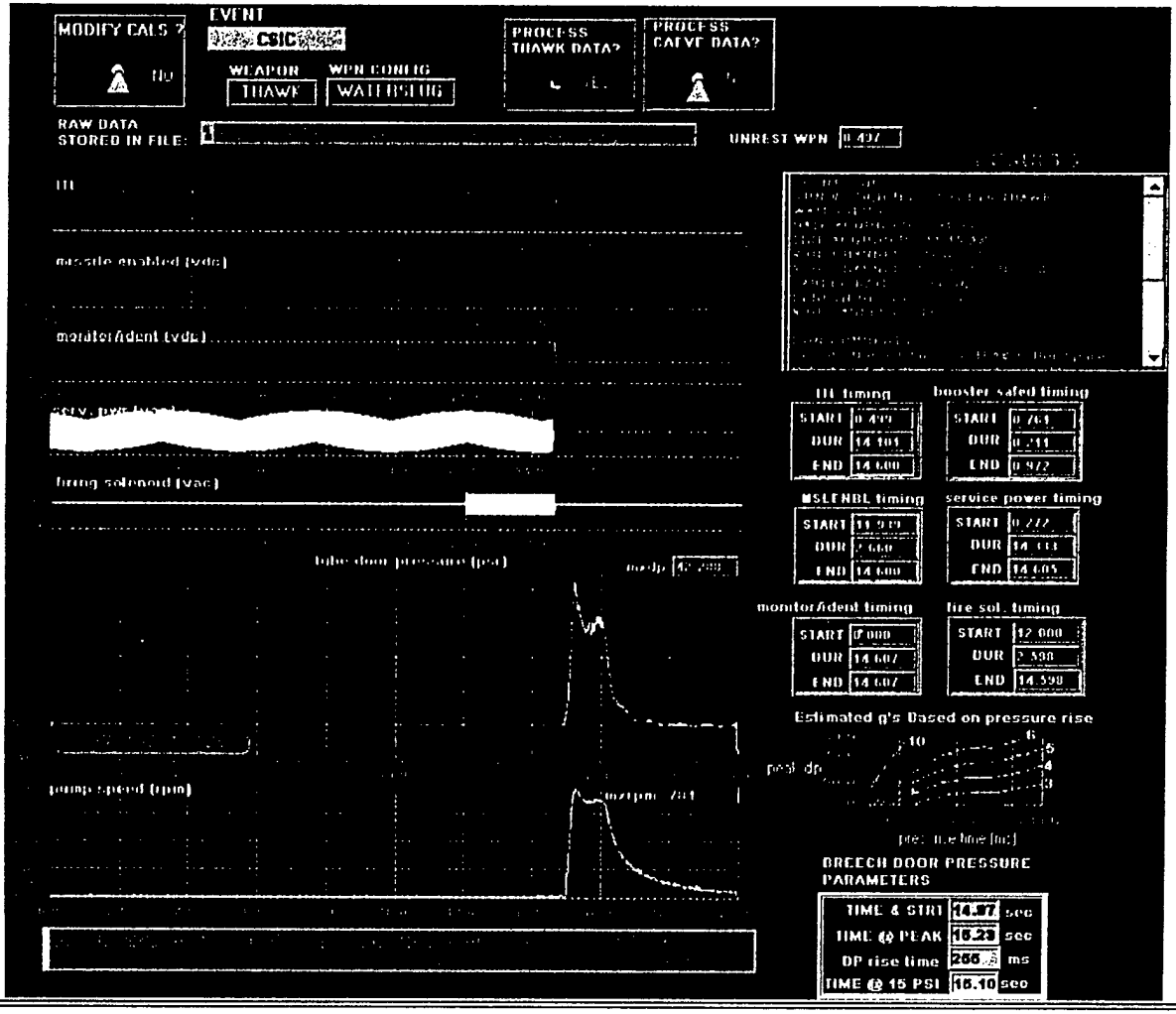

72
74
78
80
76
ADCAP
WATERSLUG
CARVER
EVSTART
EVEND
IRSTART
EVIN
IRTOMMB
MMSSTART
MMSEND
MMSDUR
FSOLSTRT
FSOLEND
SPEND
WLSCT
NAMCYCLE
Indicators
FV PASS
IN PASS
CYCPWR PASS
Manifold PASS
Mine PASS
guide Wire PASS
A Cable Severed
BREECH DOOR PROCESSING PARAMETERS
TIME @ STRT
TIME @ PEAK
TIME @ 10 PSI
Estimated g's based on pressure rise
pressure rise time area

FIG. 4

Weapons and Launcher Test Set

WALTS

TOMAHAWK POST PROCESSING SCREEN



UNCLASSIFIED

FIG. 5

Weapons and Launcher Test Set
WALTS

- **AUTOMATIC DATA REDUCTION:**

PREDETERMINED
EXIT LENGTH

COMPUTED:
ACCELERATION CURVE
EXIT VELOCITY
DISPLACEMENT

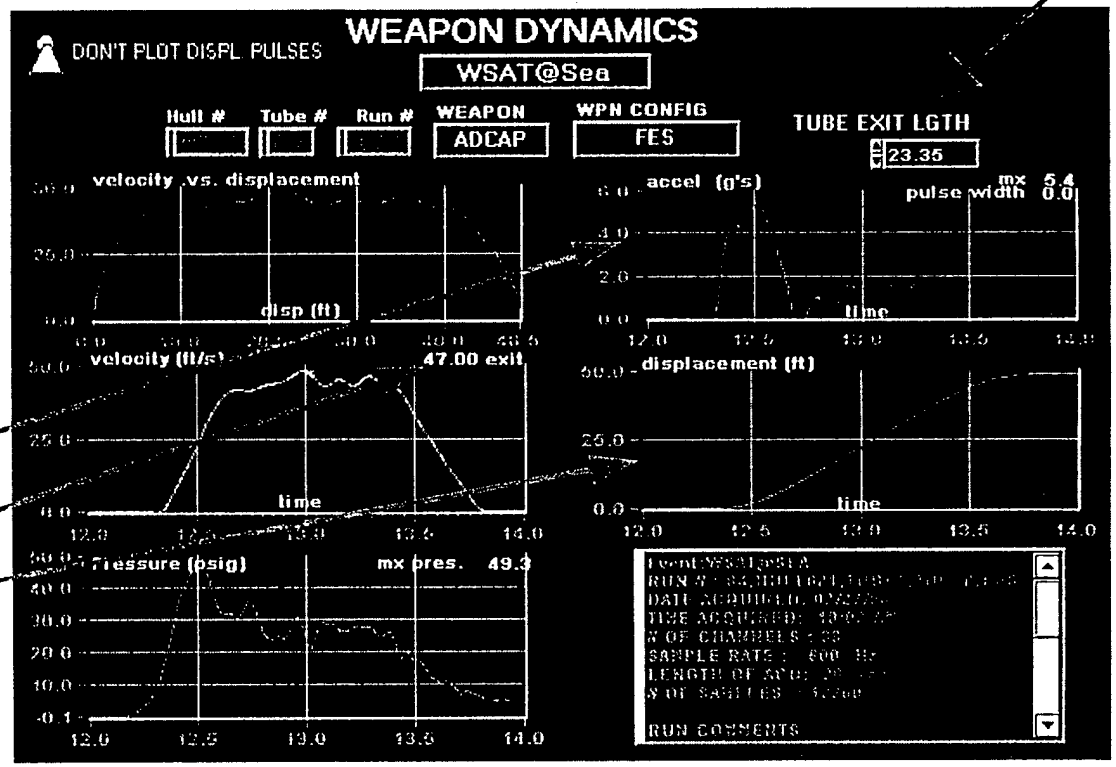


FIG.6