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1 Attorney Docket No. 80187

2
3 METHOD FOR DETERMINING LAUNCH SYSTEM
4 VELOCITY, ACCELERATION AND DISPLACEMENT
5 CERTIFICATION PARAMETERS
6

7 STATEMENT OF GOVERNMENT INTEREST

8 The invention described herein may be manufactured and used
9 by or for the Government of the United States of America for
10 governmental purposes without the payment of any royalties
11 thereon or therefore.
12

13 BACKGROUND OF THE INVENTION

14 (1) Field of the Invention

15 The present invention relates generally to launch system
16 testing, and more particularly to a method for determining
17 velocity, acceleration and displacement parameters of a
18 projectile being launched from a muzzle or tube of the launch
19 system.

20 (2) Description of the Prior Art

21 In order to certify the proper operation of a launch system,
22 such as that used to launch a torpedo from a submarine tube, it
23 is necessary to obtain velocity/time data from the projectile
24 launched by the system. Based on this data, launch velocity,

1 acceleration and displacement parameters can be derived. Current
2 certification procedures for torpedo launch systems rely on a
3 Pressure/Velocity/Displacement (PVD) housing mounted on a breech
4 door of the tube. A wire is attached to the projectile being
5 launched. In the case of a torpedo launch system certification,
6 a shape is launched, which represents the torpedo. When the
7 projectile is launched, the wire is pulled behind the projectile
8 from a reel, which spins a DC generator within the PVD housing.
9 The resulting voltage signal can be read by a computer based data
10 acquisition system and converted to a velocity/time distribution
11 plot. However, the PVD housing provides inherently noisy
12 velocity signals attributed to the gear meshing of the DC
13 generator and the wire payout being subjected to the launch
14 pulse. The noisy data must be filtered in such a way as to
15 obtain representative acceleration and displacement
16 characteristics, which can be compared to launch system
17 specifications to certify the launch system. Additionally,
18 cabling resulting in a DC shift of the data. However, simply
19 adjusting the PVD data to account for the DC shift and applying
20 standard filtering methods may compromise the calibration of the
21 PVD and cause a phase shift between the displacement and velocity
22 profiles. This may lead to erroneous velocity, displacement, and
23 acceleration time histories and inappropriate interpretation of
24 muzzle and hull exit values.

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2 SUMMARY OF THE INVENTION

3 Accordingly, it is an object of the present invention to
4 provide a method to obtain velocity signals for a launch system,
5 which minimizes the noise components of the signal.

6 Another object of the present invention is to provide a
7 method to obtain velocity signals for a launch system, which
8 maintains zero phase shifting of the data.

9 A further object of the present invention is to provide a
10 method to obtain velocity signals for a launch system, which can
11 provide a smooth fit for the velocity/time distribution in order
12 to obtain accurate acceleration and displacement characteristics
13 of the launch system.

14 Still another object of the present invention is to provide
15 a method to obtain velocity signals for a launch system, which
16 retains the frequency response appropriate for torpedo launched
17 shapes.

18 Other objects and advantages of the present invention will
19 become more obvious hereinafter in the specification and
20 drawings.

21 In accordance with the present invention, a method is
22 provided to process velocity data obtained by a PVD housing. The
23 velocity array data is captured by a computer based data
24 acquisition system. Other launch system and test parameters,

1 such as sample rate, muzzle exit length, time of acquisition,
2 decimation factor and low pass cut-off frequency, are provided as
3 inputs for the operation of the method. The method first takes
4 any data less than a predetermined value and assigns to it a
5 value of zero. This serves to eliminate stray, DC cable induced
6 voltages. The method then passes the data and input parameters
7 through a forward/reverse 5th order 6 Hz low pass elliptic
8 filter, resulting in smoothed velocity data. The filter allows
9 0.005 dB bandpass ripple and a stopband attenuation of 130 dB.
10 This smoothed data is processed to obtain and display an
11 acceleration profile and a displacement profile, as well as to
12 obtain peak acceleration, time at peak, pulse width, muzzle exit
13 velocity and time at exit.

14 By assigning a value of zero to data below a specified
15 threshold, the method eliminates cable induced voltage components
16 of the signal. The 5th order 6 Hz low pass elliptic filter
17 maintains zero phase shifting of the data and provides a smoothed
18 velocity profile of the data, from which accurate and repeatable
19 acceleration and displacement profiles can be determined. The
20 filter used in the method is chosen to retain the frequency
21 response appropriate for torpedo launched shapes.

22
23 BRIEF DESCRIPTION OF THE DRAWINGS

1 A more complete understanding of the invention and many of
2 the attendant advantages thereto will be readily appreciated as
3 the same becomes better understood by reference to the following
4 detailed description when considered in conjunction with the
5 accompanying drawings wherein like reference numerals refer to
6 like parts and wherein:

7 FIG. 1 is a schematic representation of a prior art launch
8 system for use with the present invention;

9 FIG. 2 is a flow chart of the method of the present
10 invention;

11 FIG. 3 is a flow chart of a filter selection portion of the
12 present invention; and

13 FIG. 4 is a flow chart for a second embodiment of the method
14 of the present invention.

15 16 DESCRIPTION OF THE PREFERRED EMBODIMENT

17 Referring now to FIG. 1, there is shown a prior art torpedo
18 launch system 10. In order for launch system 10 to be certified
19 as acceptable, launch system parameters must be determined to be
20 within specified ranges. These parameters include muzzle exit
21 velocity, peak acceleration and acceleration duration above
22 certain thresholds for torpedo 12 as it is launched from the tube
23 14. A PVD housing 16 is mounted on the dry side of tube 14 and
24 is attached to torpedo 12 via wire 18 passing through breech door

1 14a. As torpedo 12 is launched, wire 18 is pulled from PVD
2 housing 16, spinning DC generator 20 within housing 16. The
3 resulting voltage varies with the speed of torpedo 12 as it is
4 launched from tube 14. Computer controlled data acquisition
5 system 22 receives the voltage signals for processing.

6 Referring now also to FIG. 2, there is shown a schematic
7 flow chart of the method 50 used to determine certification
8 parameters for launch system 10. Method 50 is implemented on a
9 computer, such as computer 24, shown in FIG. 1 as controlling
10 data acquisition system 22. Method 50 begins by obtaining (at
11 52) input data from acquisition system 22. The input data
12 includes the data sampling rate used by the acquisition system
13 22, voltage signal data from DC generator 20, the length of tube
14 14 (feet), a decimation factor used in converting the analog
15 voltage signals to velocity array data (feet/second), the length
16 of acquisition, i.e., the total time period (seconds) for which
17 data was taken, and low pass cut-off frequency (Hz). Method 50
18 then converts the voltage signals to a velocity array (at 54) and
19 forces any data points less than a predetermined threshold to
20 zero (at 56). The threshold varies with the launch system being
21 tested and can be determined from empirical data for the launch
22 system. In prior art methods for determining certification
23 parameters, a velocity profile was hand fit to the voltage signal
24 data obtained. Ambient noise assumptions were made to keep the

1 derived velocity, acceleration and displacement profiles within
2 known physical parameters of the launch system. Based on this
3 empirical ambient noise data, the threshold for torpedo launch
4 system 10 is set to 0.3 feet/second. Thus step 56 is seen to
5 eliminate any nonzero levels contributed by ambient noise. The
6 data is then passed (at 58) through a forward/reverse filter to
7 smooth the velocity profile. The forward/reverse pass results in
8 zero-phase shift in time, which produces an accurate velocity-
9 time history.

10 As with the threshold, the filter used is based on empirical
11 data. In this case, the filter is chosen to match the prior art
12 hand fit profiles. FIG. 3 is a flow diagram of the method 100
13 used to choose the filtering technique for step 58. A filtering
14 technique is first chosen to smooth out raw data from previous
15 test results (at 102). The resultant plots are compared to the
16 hand fit profiles for the same data (at 104). The filtering
17 technique is adjusted until the filtered profiles match the hand
18 fit profiles (at 106). Additionally, the acceleration and
19 displacement profiles based on the filtered profiles are checked
20 to ensure no known physical parameters of the launch system, such
21 as the system frequency response, are exceeded (at 108). The
22 filtering technique is further adjusted until the profiles match
23 and the physical parameters are within known bounds (at 110).

1 Using the filtering choosing technique 100 results in a 5th
2 order, 6 Hz low pass elliptical filter chosen for the launch
3 system 10. The filter allows 0.005 dB bandpass ripple and a
4 stopband attenuation of 130 dB. Once the velocity profile has
5 been smoothed, acceleration and displacement profiles can be
6 generated (at 60). The acceleration and displacement profiles
7 are generated from the velocity profile using standard
8 mathematical techniques. Additionally, certification parameters,
9 such as peak acceleration, time at peak, pulse duration and
10 muzzle exit velocity, are calculated (at 62). The profiles and
11 parameters are then output and displayed (at 64). Based on the
12 output profiles and parameters, the launch system 10 may be
13 certified for use, or marked for adjustment, repair, or
14 rebuilding (at 66).

15 The invention thus described provides a method that
16 eliminates hand fitting of velocity data during launch system
17 certification. The method is implemented on a computer and
18 begins by first minimizing ambient noise effects on the data by
19 assigning a value of zero to data below a specified threshold.
20 The threshold is determined by empirical analysis of previous
21 data. A forward/reverse filter is applied to the data to smooth
22 the resultant velocity profile. The forward/reverse filter
23 maintains zero phase shift in time so as to provide an accurate
24 velocity-time history. The specific filter technique used is

1 chosen to match hand fit profiles for previously collected data
2 and to maintain results within physical parameters of the launch
3 system.

4 Although the present invention has been described relative
5 to a specific embodiment thereof, it is not so limited. While
6 the method has been described for the torpedo launch system of
7 FIG. 1, it can be used to obtain certification parameters for
8 other types of systems, where smoothed data is required. As an
9 example, a second embodiment provides acceleration estimates for
10 torpedo shapes based on breech door pressure data from water slug
11 tests. A water slug test launch consists of filling the tube 14,
12 which normally holds the torpedo, with water and then operating
13 the launch system to eject the water from the tube 14. For this
14 embodiment, data acquisition system 22 obtains pressure data from
15 sensors at breech door 14a. FIG. 4 shows the method, designated
16 as 50', as applied to the breech door pressure data. First, data
17 acquisition system 22 obtains the breech door pressure data from
18 a water slug test (at 52'). For the embodiment of FIG. 4, no
19 conversion is necessary and system cable voltages do not affect
20 the data. Rather, method 50' adjusts the pressure data to
21 eliminate differential pressure due to depth (at 55). The filter
22 is applied (at 58'), a pressure profile is generated (at 60') and
23 various pressure parameters can be calculated (at 62') in a
24 manner similar to that shown in FIG. 2. These parameters include

1 peak differential pressure (relative to base pressure), time at
2 which pressure starts to rise, time at which peak pressure
3 occurs, the time differential between first rise and the time at
4 which a differential pressure of 15 psi is reached (considered to
5 correlate with first motion of a torpedo). The parameters are
6 displayed (at 64') along with a family of acceleration curves
7 based on empirical data (at 68). The point corresponding to peak
8 pressure at time of peak is displayed against the acceleration
9 curves (at 70). The estimated peak acceleration of a weapon
10 launched by the system can then be interpolated from the two
11 acceleration curves the point lies between (at 72).

12 Depending on the launch system being tested, the
13 certification parameters generated by the method may vary. The
14 method has been described as being implemented on computer 24,
15 which controls acquisition system 22. It can be easily seen that
16 computer 24 can be completely separate from acquisition system
17 22, or may be integrated within system 22. It is to be noted
18 that, in order to obtain maximum benefit from the method,
19 previous test data should be available to provide sufficient data
20 for empirical analyses to determine the threshold and filtering
21 technique.

22 Thus, it will be understood that many additional changes in
23 the details, materials, steps and arrangement of parts, which
24 have been herein described and illustrated in order to explain

1 the nature of the invention, may be made by those skilled in the
2 art within the principle and scope of the invention.

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1 Attorney Docket No. 80187

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METHOD FOR DETERMINING LAUNCH SYSTEM

4

VELOCITY, ACCELERATION AND DISPLACEMENT

5

CERTIFICATION PARAMETERS

6

7

ABSTRACT OF THE DISCLOSURE

8 A method is provided to process system test data to
9 determine certification parameters of the system based on the
10 test data. For a torpedo launch system, the velocity data is
11 generated by a Pressure/Velocity/Displacement housing interfaced
12 with a computer based data acquisition system and known launch
13 system and test parameters, such as sample rate, muzzle exit
14 length, time of acquisition, decimation factor and low pass cut-
15 off frequency are provided as inputs. The method forces assigns
16 a value of zero to any data less than a predetermined threshold
17 in order to eliminate non-zero levels contributed by ambient
18 noise. The method then passes the data through a filter chosen
19 to agree with hand fit smoothing methods, so as to obtain a
20 smoothed velocity profile. The smoothed data is processed to
21 obtain and display an acceleration profile and a displacement
22 profile, as well as data points for peak acceleration, time at
23 peak, acceleration pulse width, muzzle exit velocity and time at
24 exit.

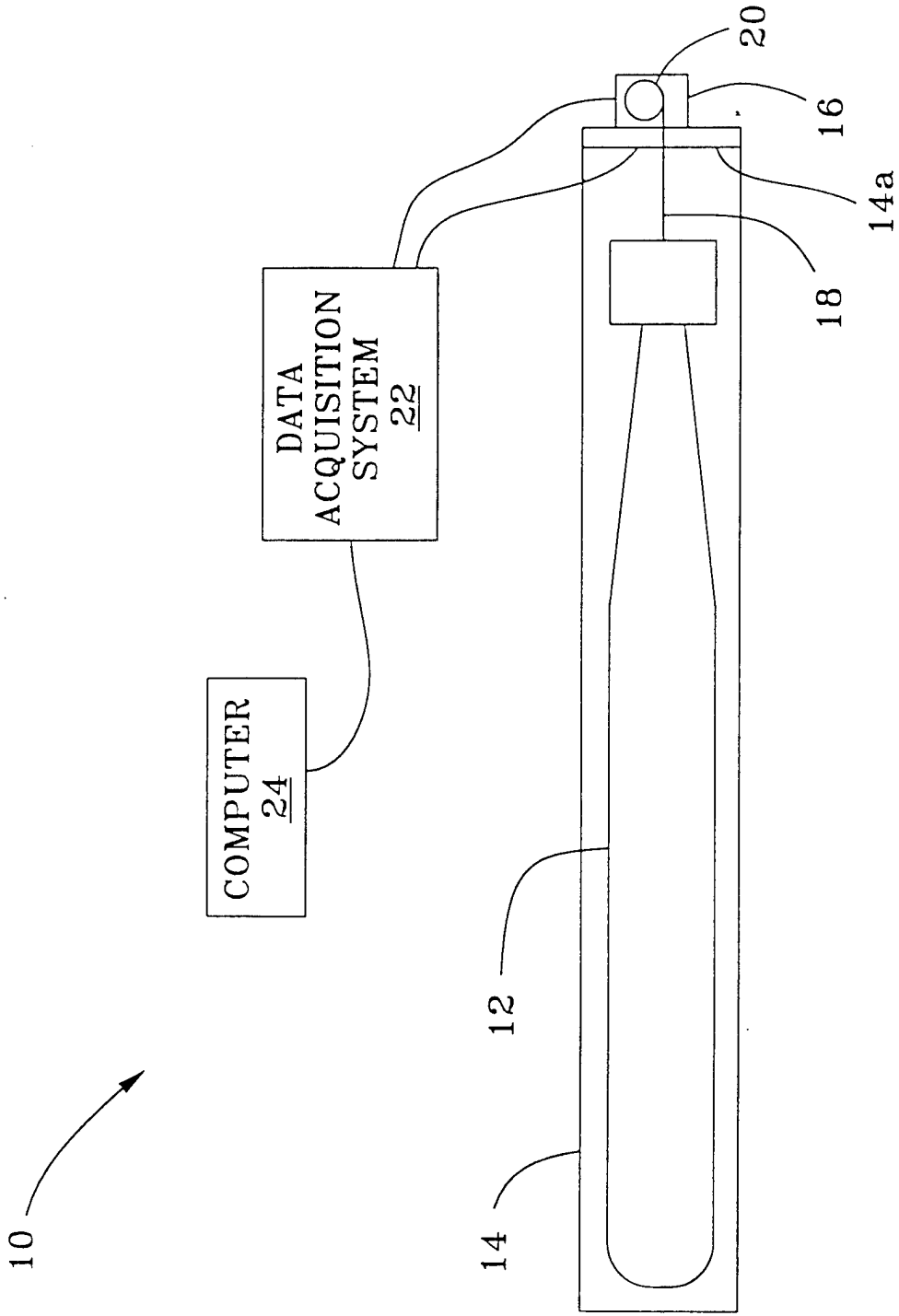


FIG. 1
PRIOR ART

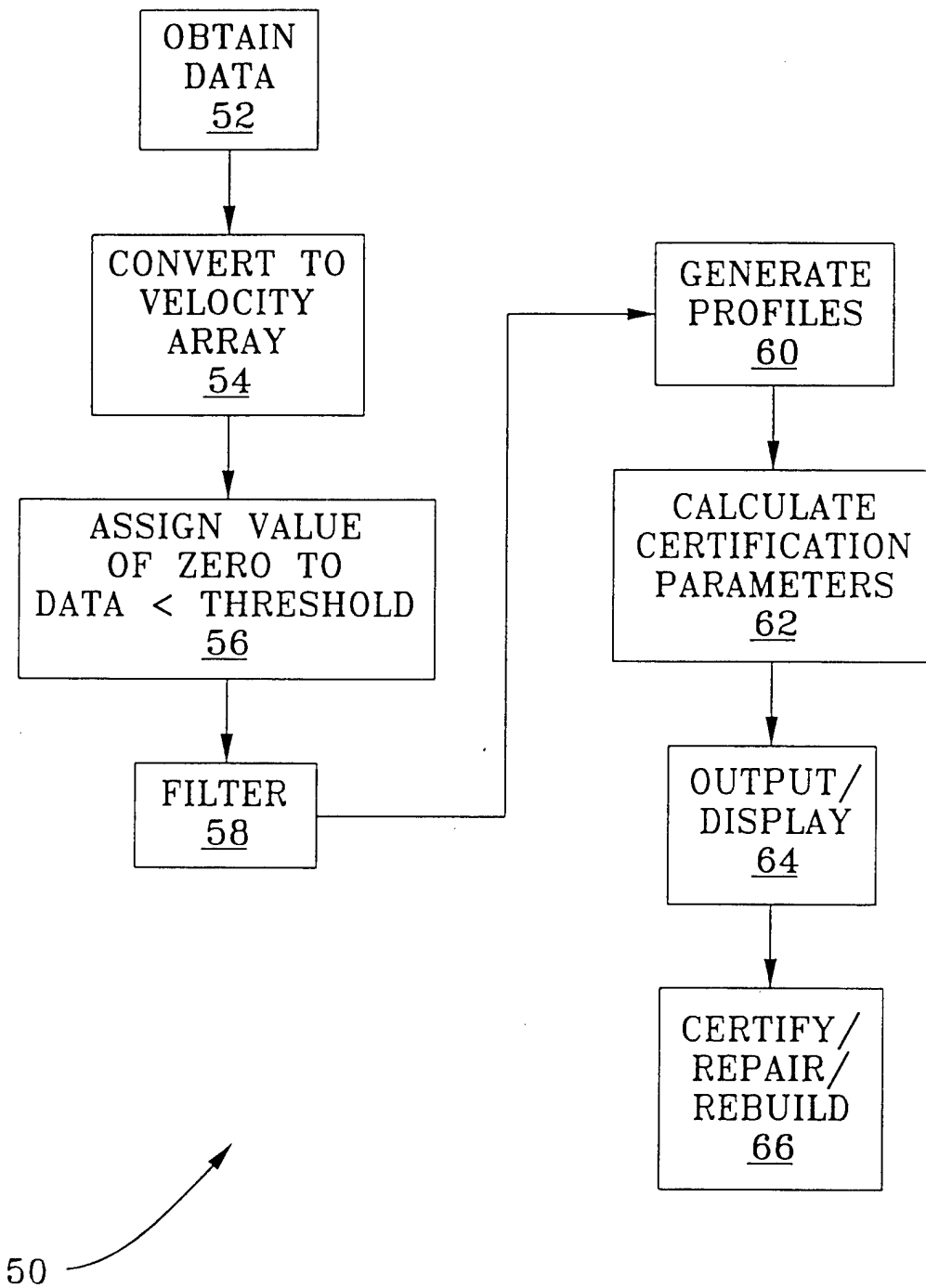


FIG. 2

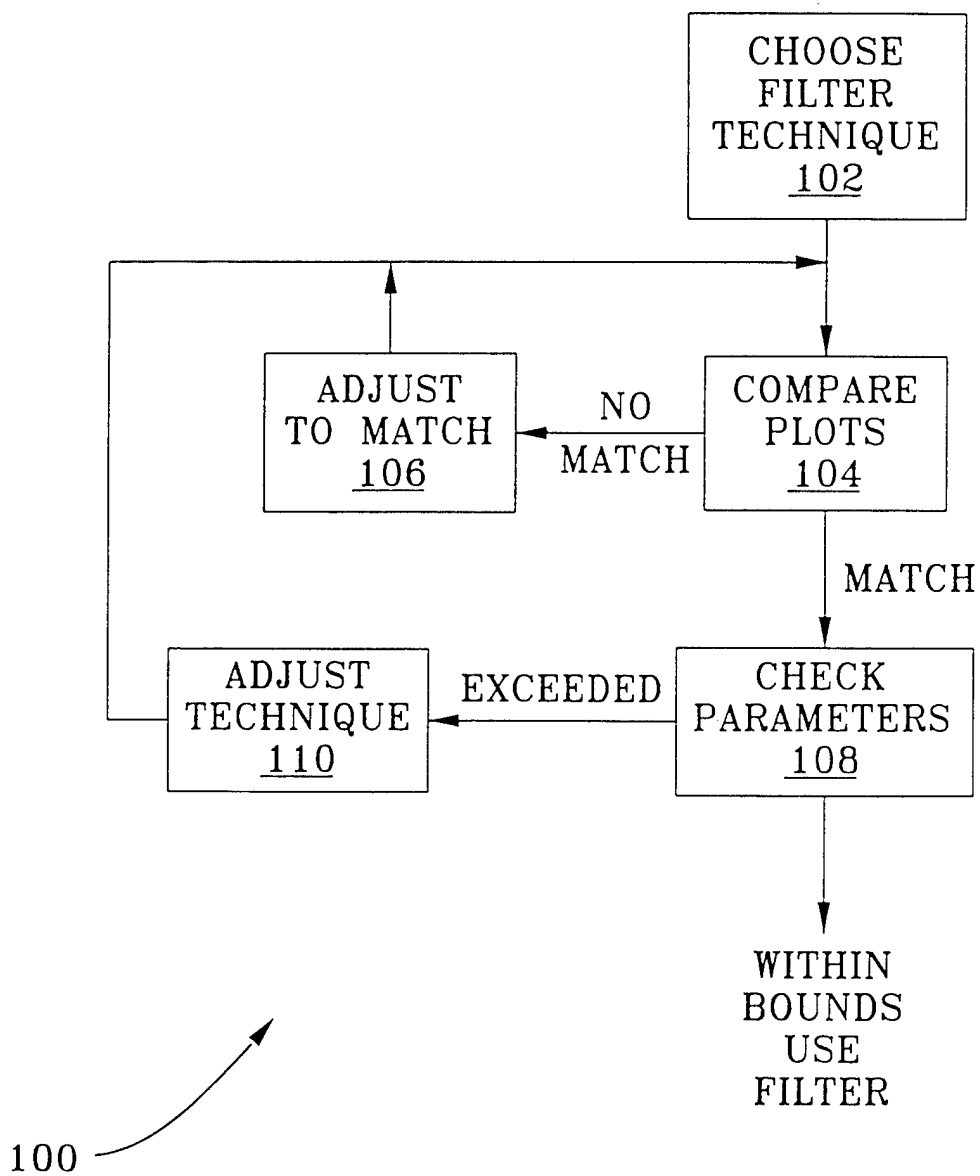


FIG. 3

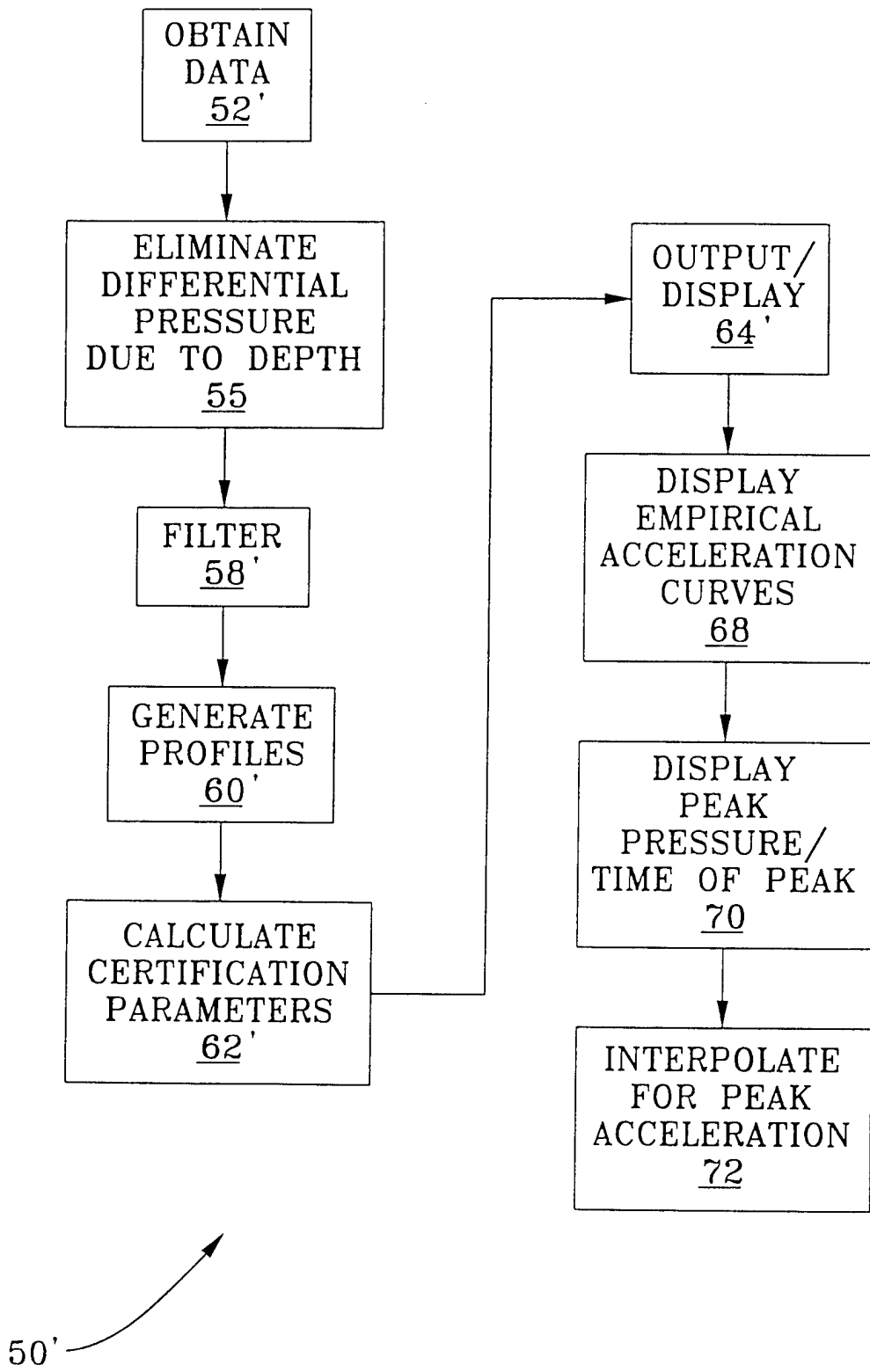


FIG. 4