SAE Aerospace — An SAE International Group	AEROSPACE RECOMMENDED PRACTICE	ARP4895	REV. A
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(R) Flight Control Actuators - Dynamic Seals,
Collection of Duty Cycle Data

RATIONALE

There is a trend to design airplanes with less natural stability than before, now relying on stability augmentation systems. Reduction of the size of the vertical and horizontal stabilizers is considered as a major weight and drag reduction opportunity, therefore making stability augmentation systems more and more active, depending on the degree of stability relaxation or instability left to the natural aircraft. Moreover it is to be noted that imperfections of the control laws, non-linearities in hydro mechanical equipment etc. may generate control surface position servo loop limit cycles, detrimental to the dynamic seal life.

The two most significant factors affecting seal life are the number of small amplitude reversals and the total stroke distance.

This is the reason why an automatic, cost effective method for assessing hydraulic actuator dynamic seal duty cycle data at different stages of development of an aircraft project becomes a very useful tool.

1. SCOPE

This SAE Aerospace Recommended Practice (ARP) provides an algorithm aimed to analyse flight control surface actuator movements with the objective to generate duty cycle data applicable to hydraulic actuator dynamic seals.

This algorithm can be used to process digitally recorded actuator positions, generated either by pure simulation, or hardware-in-the-loop simulation, or flight test of full scale demonstrator of new aircraft, of new aircraft models in development, or of in-service aircraft, depending on what is available at different stages of the aircraft development and the purpose of the duty cycle investigation. This generated duty cycle data can be used as a basis for defining dynamic seal life requirements, dynamic seal life testing, or to assess the impact of control law or other changes to dynamic seal behavior.

2. REFERENCES

2.1 Applicable Documents

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or 724-776-4970 (outside USA), www.sae.org.

There are no applicable documents.

2.2 Other Applicable References

Royal Aircraft Establishment Report 69096 - An Investigation into the Duty Cycle of Powered Flying Controls, F. Holombek, May 1969

3. BACKGROUND

3.1 Past Practice

Actuator displacement duty cycle requirements used in the qualification of past fly-by-wire aircraft have been established analytically from a limited amount of flight test data. Studies analyzing flight test data have been very limited in scope. A Royal Aircraft Establishment study in the late 1960s indicated that the control actuator usage for aircraft with unaugmented mechanical control systems was less "arduous" than the design requirements. No systematic, quantified investigation into the flight control demands has been undertaken for highly augmented or totally fly-by-wire aircraft. A major concern in the development of actuators for this type aircraft is actuator endurance and particularly seal life.

3.2 Recommended Practice

Displacement duty cycle data should be collected from aircraft that are advanced technology demonstrators and full-scale development programs. The collection of data during the development testing phase of new aircraft is very cost-effective because these aircraft are normally highly instrumented and all the data are recorded on-board the aircraft and/or in a telemetry ground station.

Normally, several flight control system parameters are monitored on all test aircraft to assure safety of flight. The parameters typically include: aircraft rates and accelerations, pilot primary control inputs and control surface positions.

The duty cycle collection method identified in this ARP makes use of a computer algorithm which can run real time in a telemetry ground station. Data recorded on board the aircraft can be postflight processed if a real time telemetry ground station is not available.

Limitations for real time data processing are telemetered parameters, data sample rate, and ground station capability. If small reversals are considered important, sample rates and timing of the sampling may be statistically important.

Limitations for postflight nonreal time processing of data are the cost and logistics of replaying hundreds of hours of data tapes.

However the described algorithm can also be used in other contexts as mentioned in the scope

4. ACTUATOR DISPLACEMENT DATA ACQUISITION

4.1 Digital Data Acquisition

The position data sampling frequency shall be selected high enough, not to lose information. Theoretical minimum is twice the frequency of the movement to be analyzed. If the movement frequency is not precisely known it is safe to consider a margin, typically a factor of five rather than two .

4.2 Data Identification and Collection

In order to manage the collection of actuator displacement data, all of the actuator reversals shall be counted and the displacement amplitudes be lumped in a limited number of levels based on percent of stroke ranges. Because the effects of an augmentation system is a major area of interest, the number of smaller reversals should have better resolution than the larger amplitude reversals. The data should be segregated by flight phase; e.g., ground operation, takeoff/landing configuration, and other regimes through the flight envelope Data Analysis:

An actuator displacement usage algorithm should operate as shown in Figure 1. The algorithm is based on a three point approach to determine the existence of a peak or valley. The algorithm identifies a peak when the middle point has a value greater than or equal to the preceding point and has a value greater than the succeeding point. Likewise, a valley is identified when the middle point has a value less than the preceding point and has a value less than or equal to the succeeding point. The stroke can then be determined by calculating the displacement between the peak and the valley. To eliminate the possibility of identifying incorrect peaks or valleys, for instance due to data dropouts, the algorithm calculates the actuator rate between successive points. If the calculated rate exceeds the actuator maximum rate capability, the algorithm ignores that data point. Data processed by the algorithm either in real time or by replay can be stored and sorted into displacement "bins" i.e., 0-2%, 2-5%, 5-10%, 10-25%, 25-50%, 50-75%, 75-100%. The data can then be presented in a histogram format. The number of displacement bins in this example was chosen to be similar to the duty cycle recommendation presented in ARP1281. The user of this algorithm can select any number displacement range bins. A flow chart for the Actuator Reversal Calculation Program is presented in Figure 2.

4.3 Data Sample

An example of flight test data that has been processed by the algorithm is shown in Figures 3 and 4. The data for this example was chosen because Parade Formation is a nonmaneuvering flight phase that requires highly precise pilot inputs and results in a larger number for small actuator displacements. The symbols shown on the plots in Figure 3 shows points which are picked by the algorithm without a minimum displacement window. Figure 4 shows the results of incorporating a 0.25% (0.09°) minimum displacement window. The minimum displacement window is a user defined parameter which can be set at any value to prevent the algorithm from processing noise in the instrumentation system. It may be based on the knowledge of the quality of the acquisition chain, in terms of noise or resolution, or actual actuator position servo loop performance. It shall not be ignored that actual position threshold may be lower than specified. The 0.25% minimum displacement was chosen for the example because it corresponds to the actuator threshold. Histograms of the data from Figures 3 and 4 are presented in Figure 5.

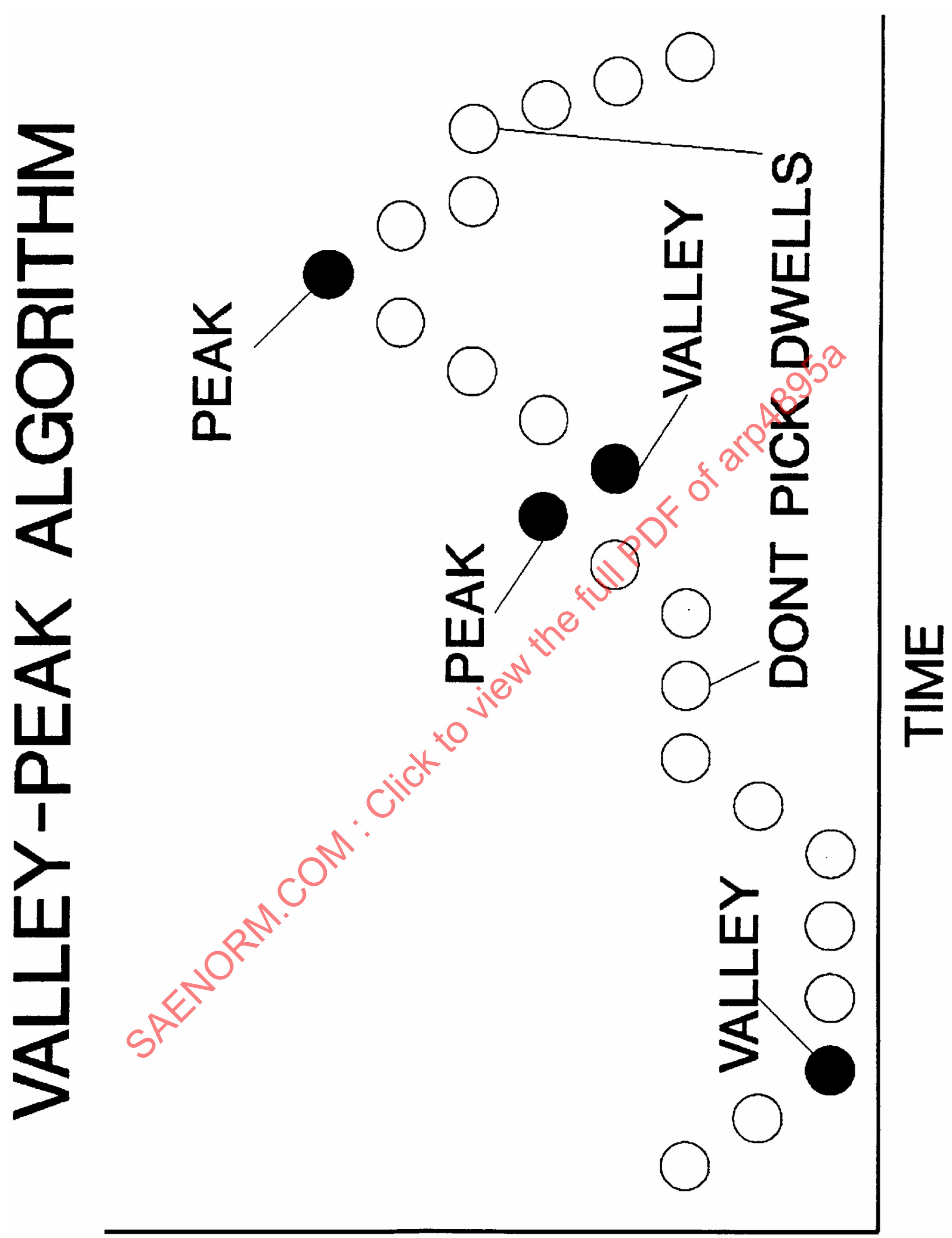


FIGURE 1 - VALLEY-PEAK ALGORITHM

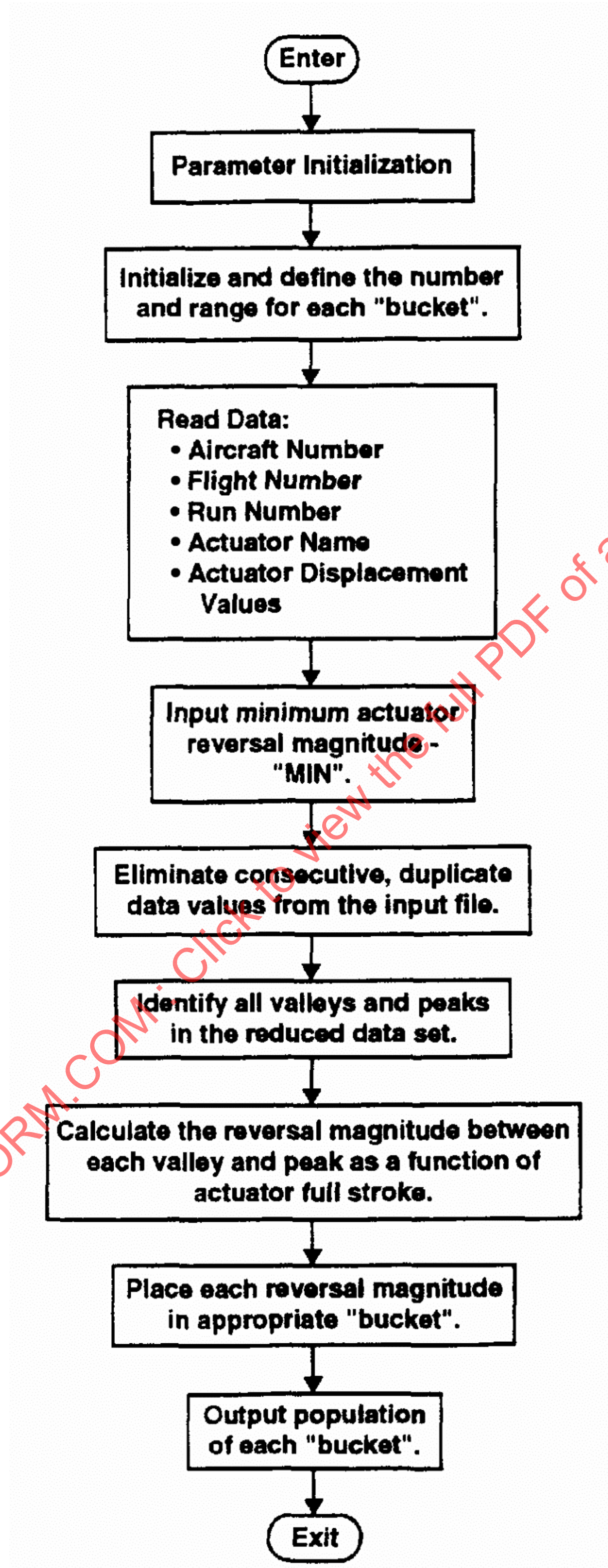
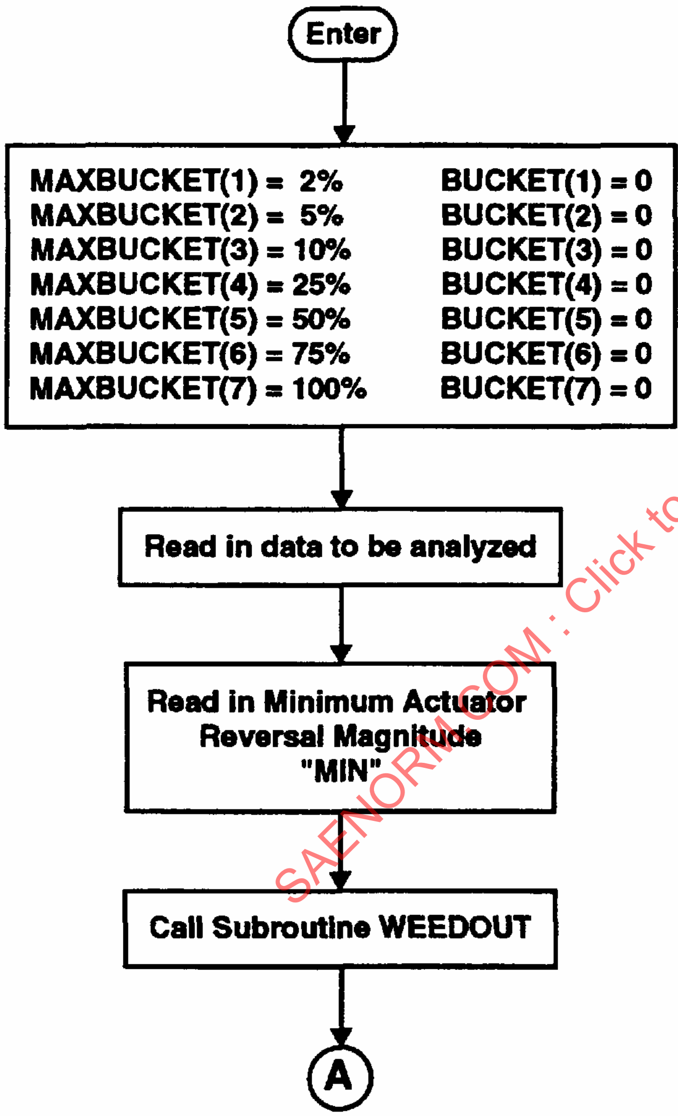


FIGURE 2 - ACTUATOR REVERSAL CALCULATION PROGRAM

Initialization



Seven distinct "buckets" are defined with each "bucket" representing a percentage range for full actuator stroke. This range is defined by MAXBUCKET. There is also a counter called BUCKET which tallies the number of reversal magnitudes that fall into each respective "bucket" range.

Data can be from aircraft flight test, ground test, or laboratory testing. Data may consist of aircraft number, flight number, run number, test number, name of actuator being analyzed, and actuator displacement values.

Defines the minimum actuator stroke to be used in determining if a peak or a valley has occurred.

Eliminates all consecutive, duplicate data values from the input file.

FIGURE 2A - ACTUATOR REVERSAL CALCULATION PROGRAM

Subroutine WEEDOUT

Purpose: Eliminates duplicate data values. Reduces processing time required when looking for a peak or a valley.

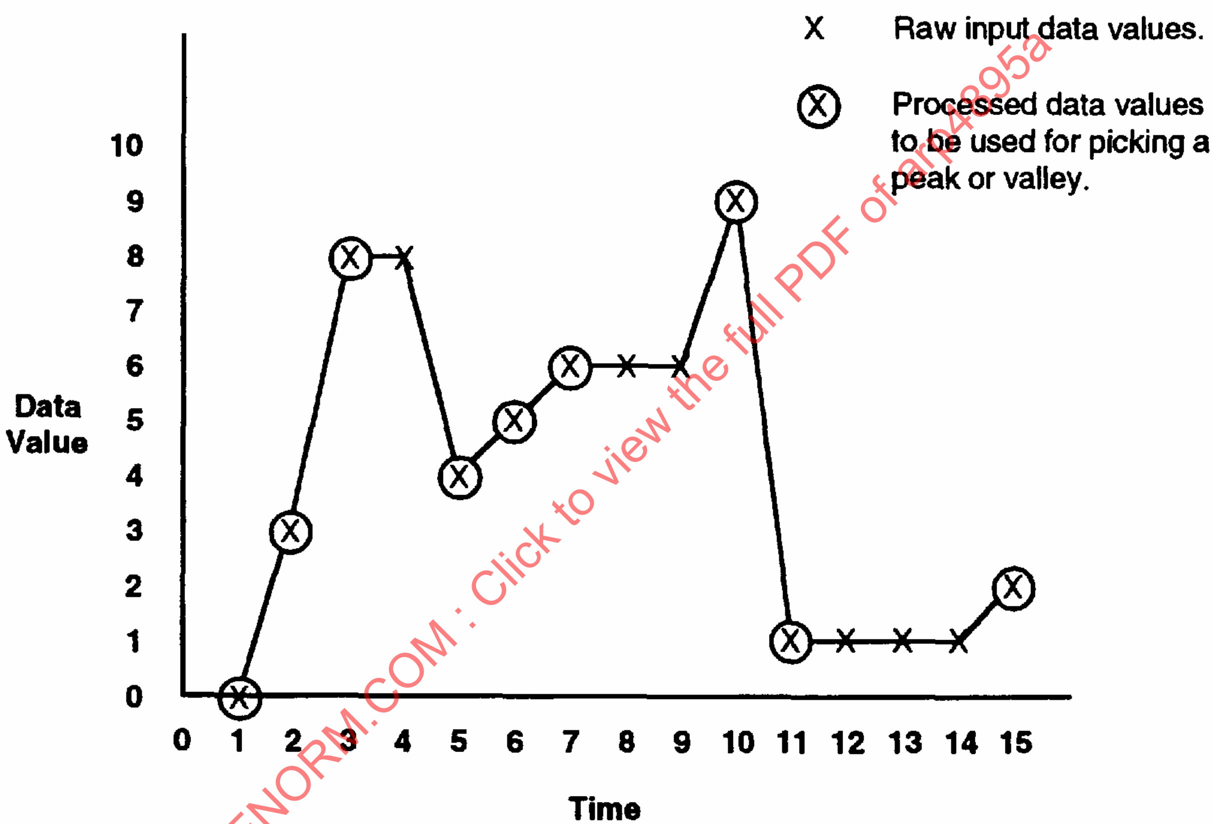


FIGURE 2B - ACTUATOR REVERSAL CALCULATION PROGRAM

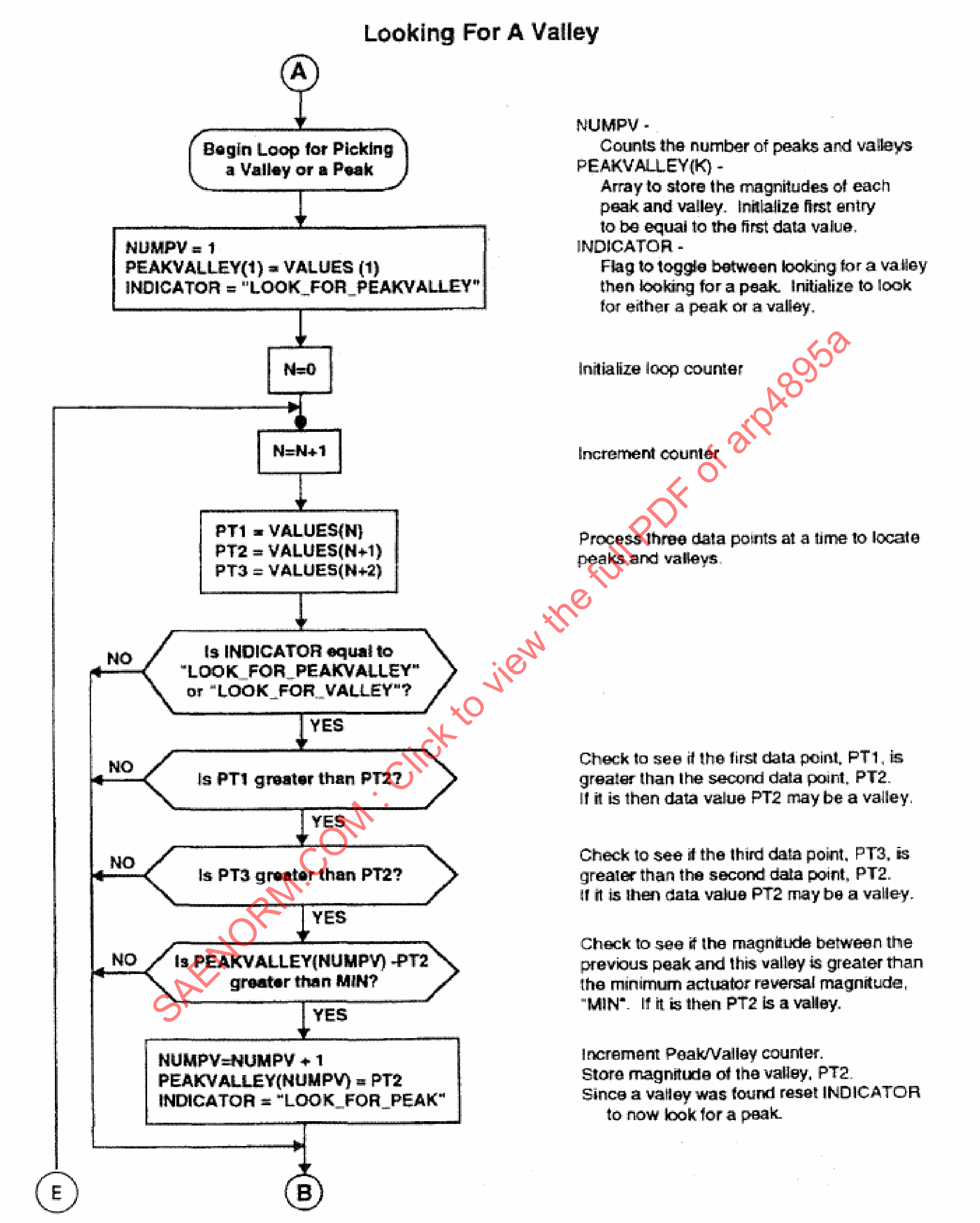


FIGURE 2C - ACTUATOR REVERSAL CALCULATION PROGRAM

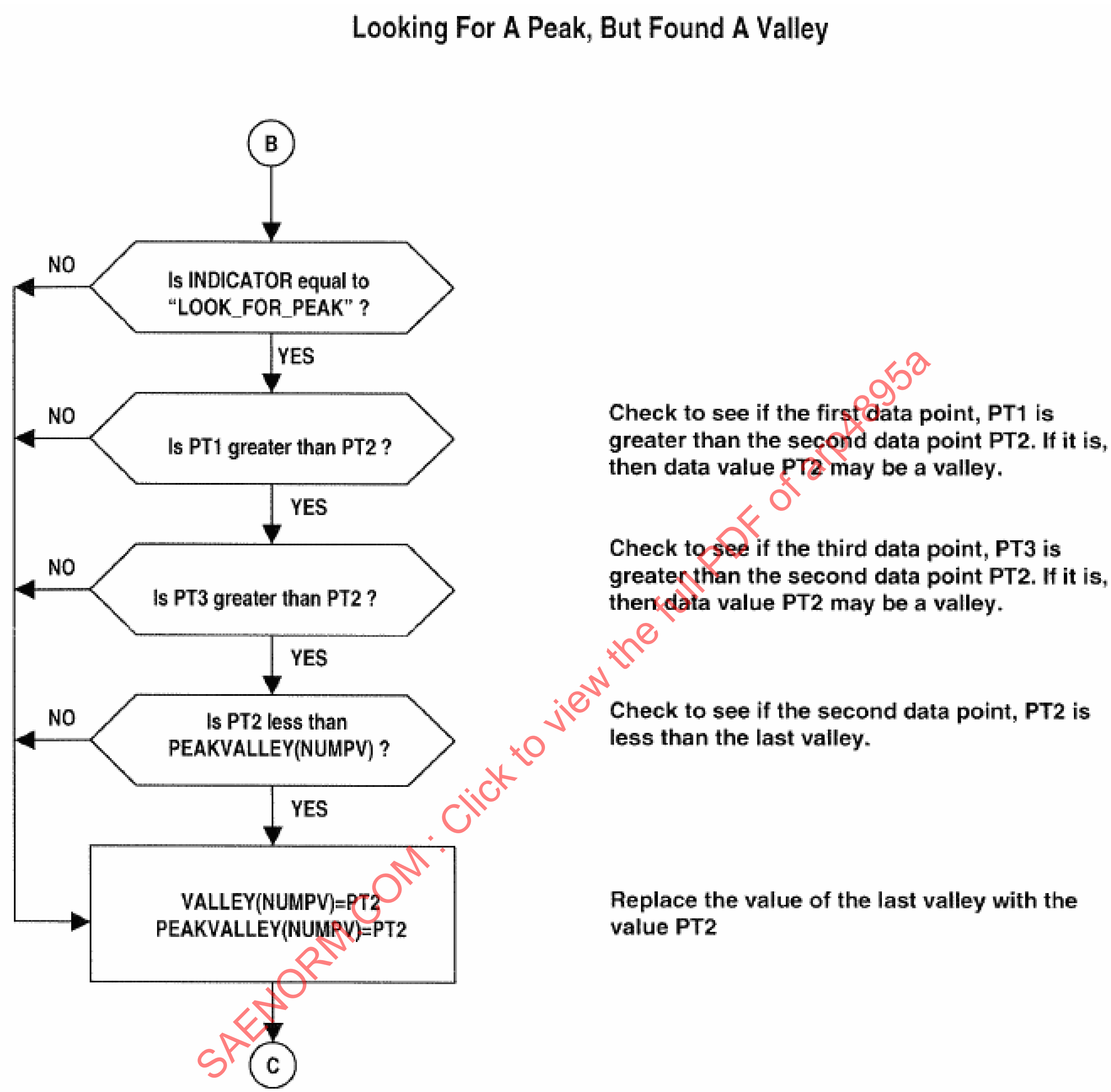


FIGURE 2D - ACTUATOR REVERSAL CALCULATION PROGRAM

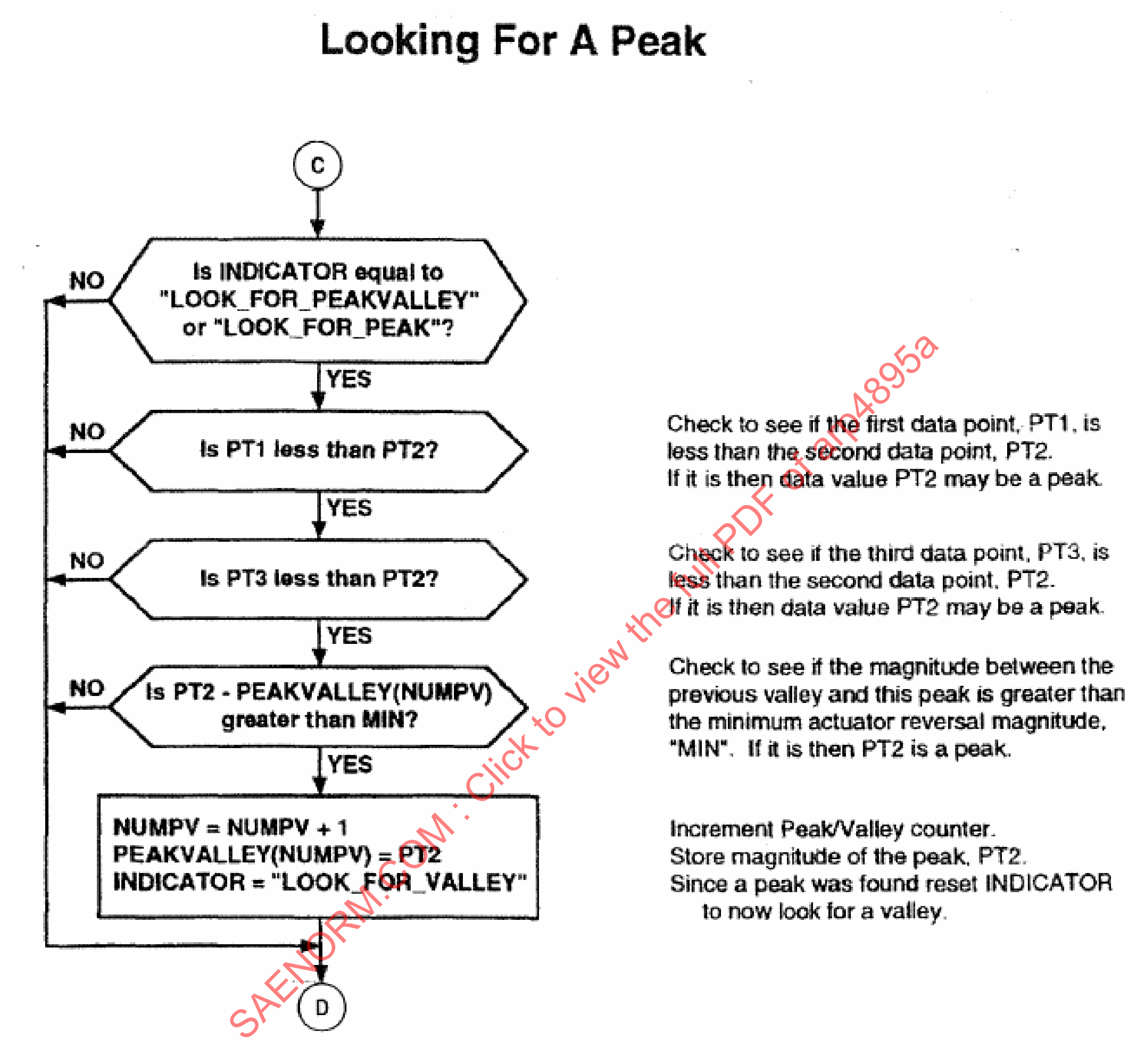
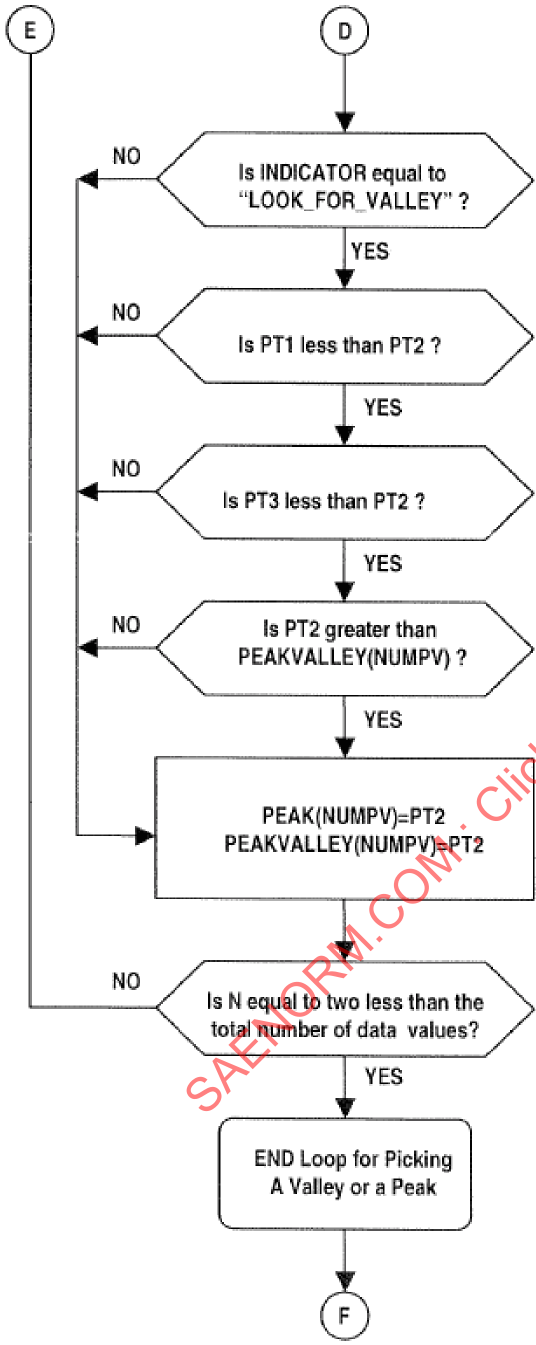


FIGURE 2E - ACTUATOR REVERSAL CALCULATION PROGRAM

Looking For A Valley, But Found A Peak



Check to see if the first data point, PT1 is less than the second data point PT2. If it is, then data value PT2 may be a peak.

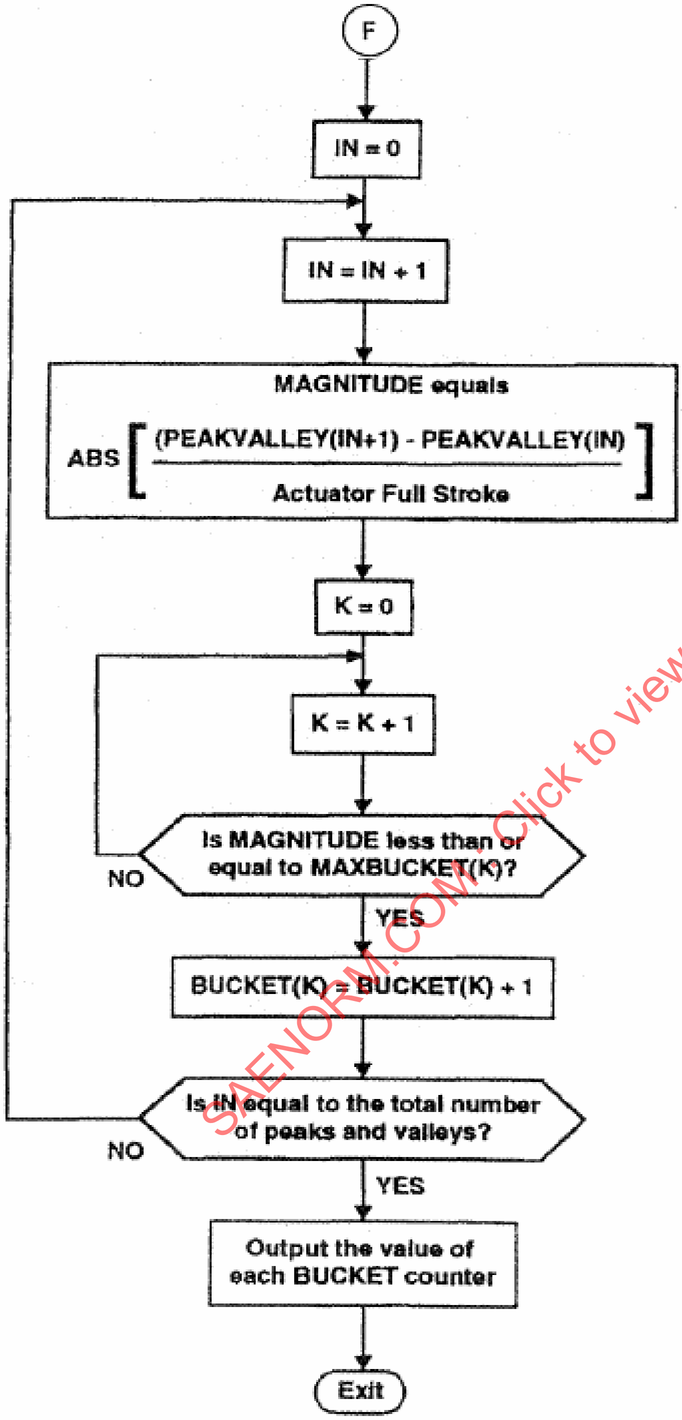
Check to see if the third data point, PT3 is less than the second data point PT2. If it is, then data value PT2 may be a peak.

Check to see if the second data point, PT2 is greater than the last peak.

Replace the value of the last peak with the value PT2

FIGURE 2F - ACTUATOR REVERSAL CALCULATION PROGRAM

Actuator Reversal Magnitude Calculation



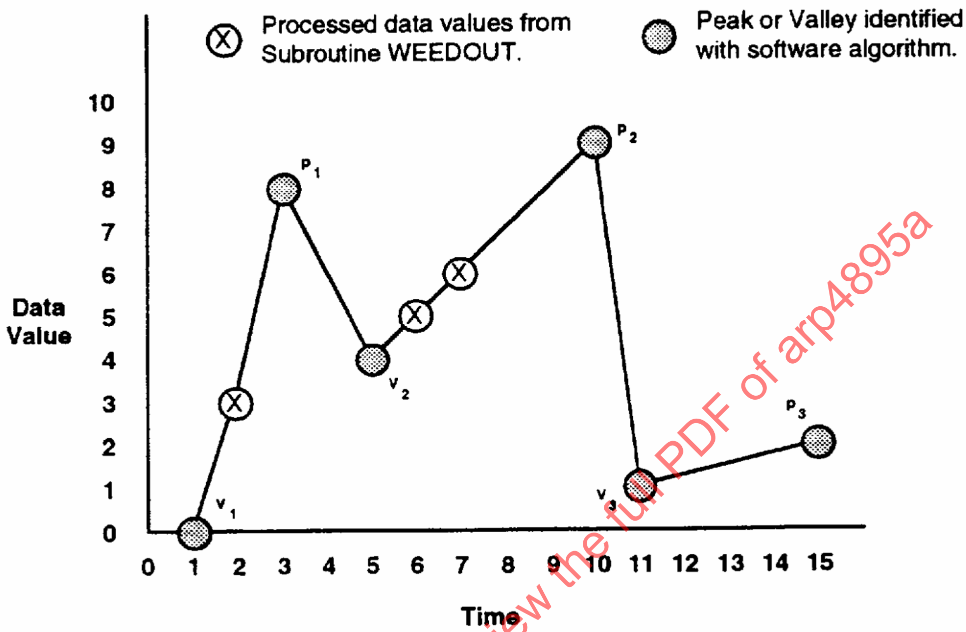
Start loop to calculate magnitude between each peak and valley as a function of actuator full stroke and put into corresponding "buckets". IN is a counter that increments through all the peaks and valleys previously defined.

Initialize flag K to loop through all seven "buckets" to determine which "bucket" counter to increment based on the value for MAGNITUDE.

FIGURE 2G - ACTUATOR REVERSAL CALCULATION PROGRAM

Program Outputs

Peak and Valley Identification



Actuator Reversal Tabulation

	Delta Actuator Stroke (Percent) *
$V_1 \rightarrow P_1$	80%
$P_1 \rightarrow V_2$	40%
$V_2 \rightarrow P_2$	50%
$P_2 \rightarrow V_3$	80%
$V_3 \rightarrow P_3$	10%

Actuator Reversals

Bucket	Counts
0 - 2%	0
2 - 5%	0
5 - 10%	1
10 - 25%	0
25 - 50%	1
50 - 75%	1
75 - 100%	2

* Assumes a value of 10 for maximum actuator stroke.

FIGURE 2H - ACTUATOR REVERSAL CALCULATION PROGRAM