

Fig. 1

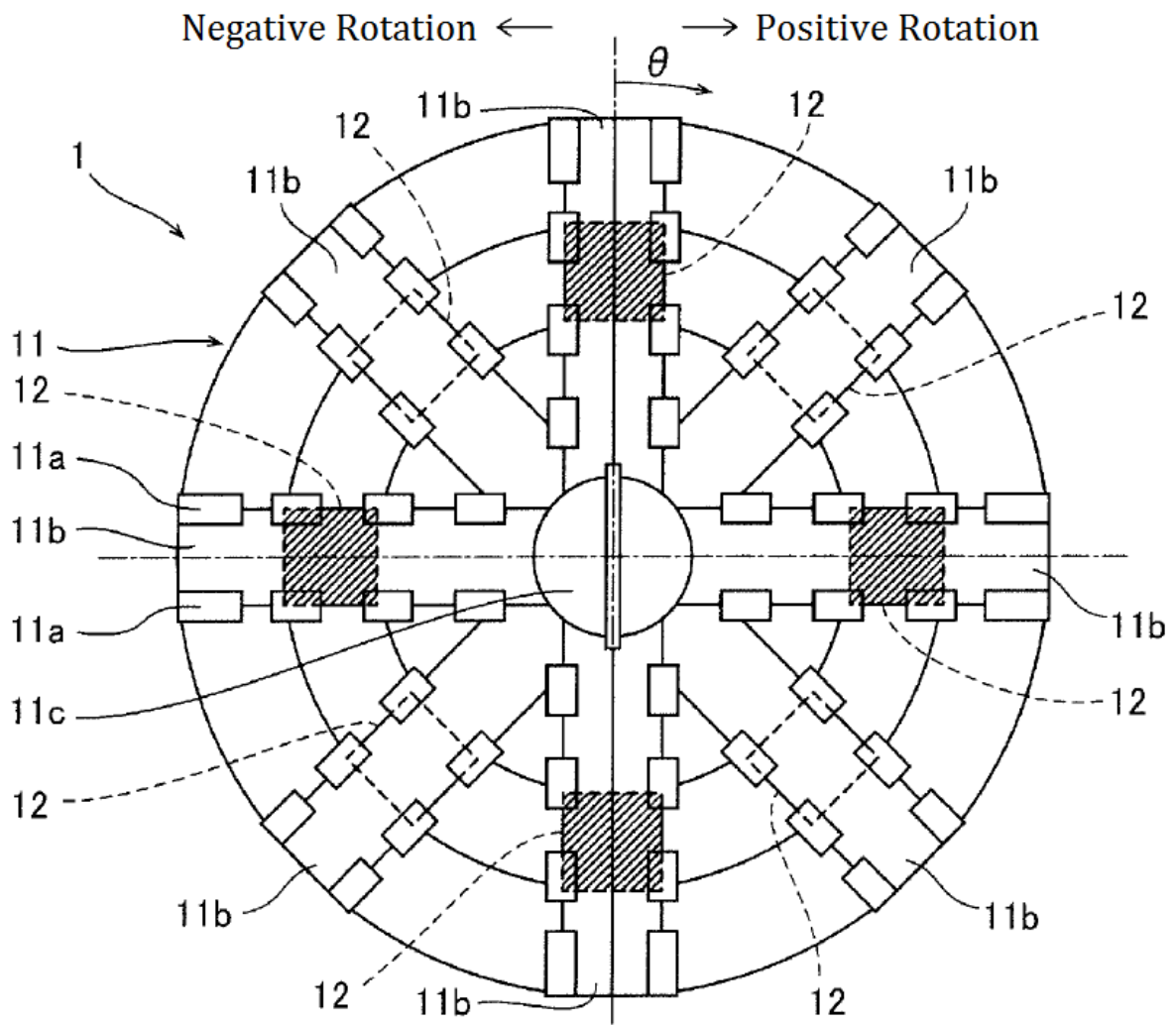


Fig. 2

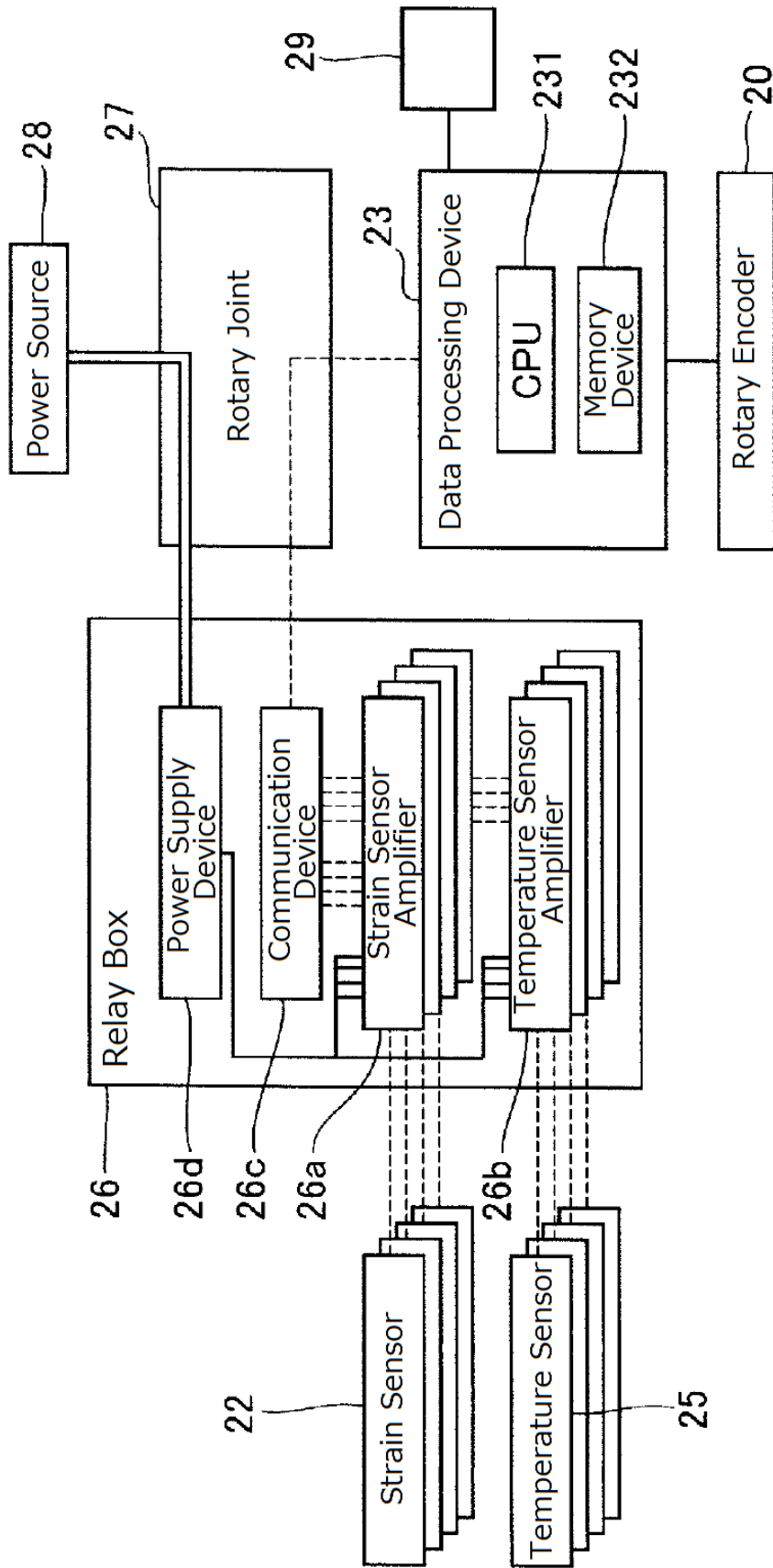


Fig. 3

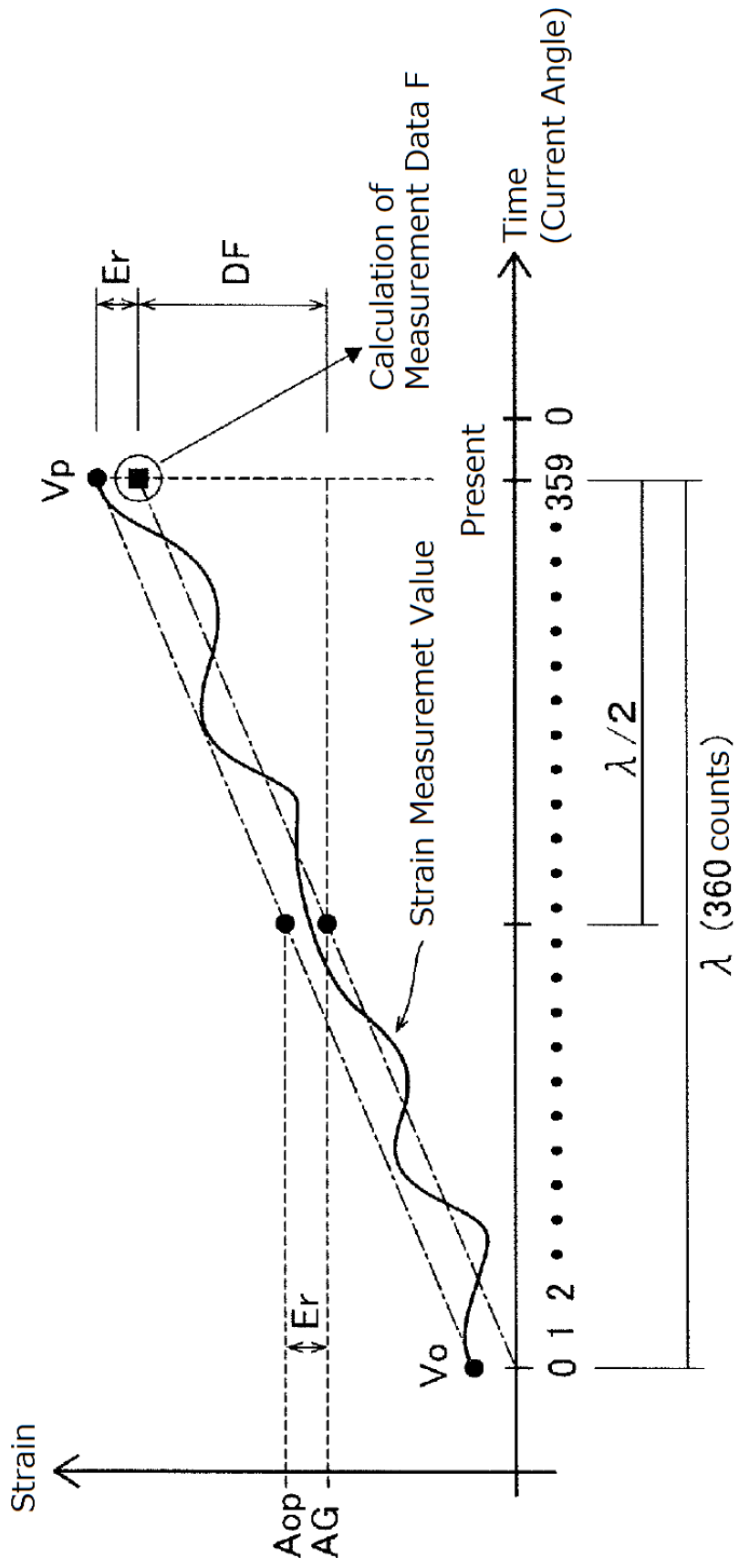


Fig. 4

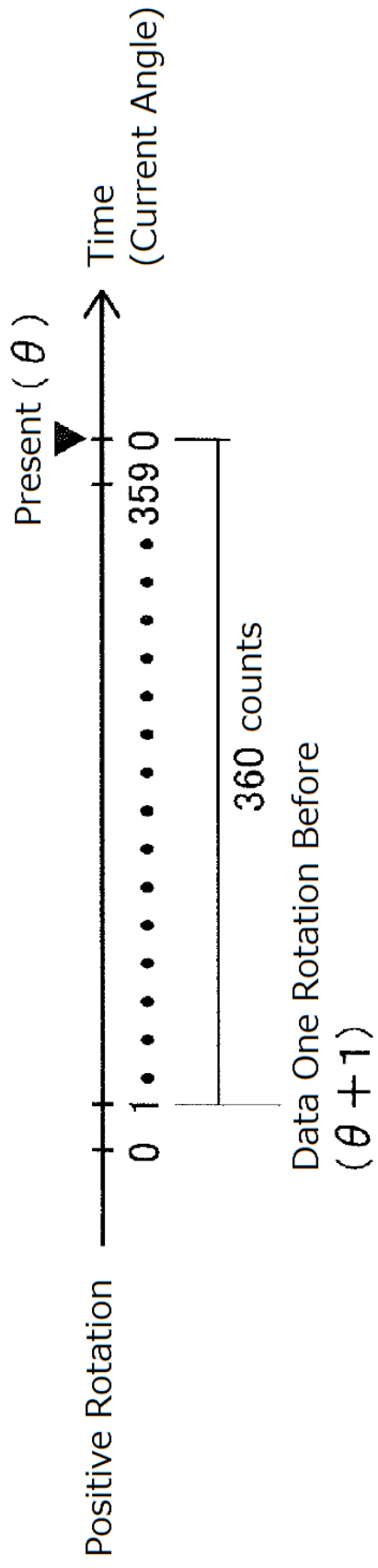


Fig. 5

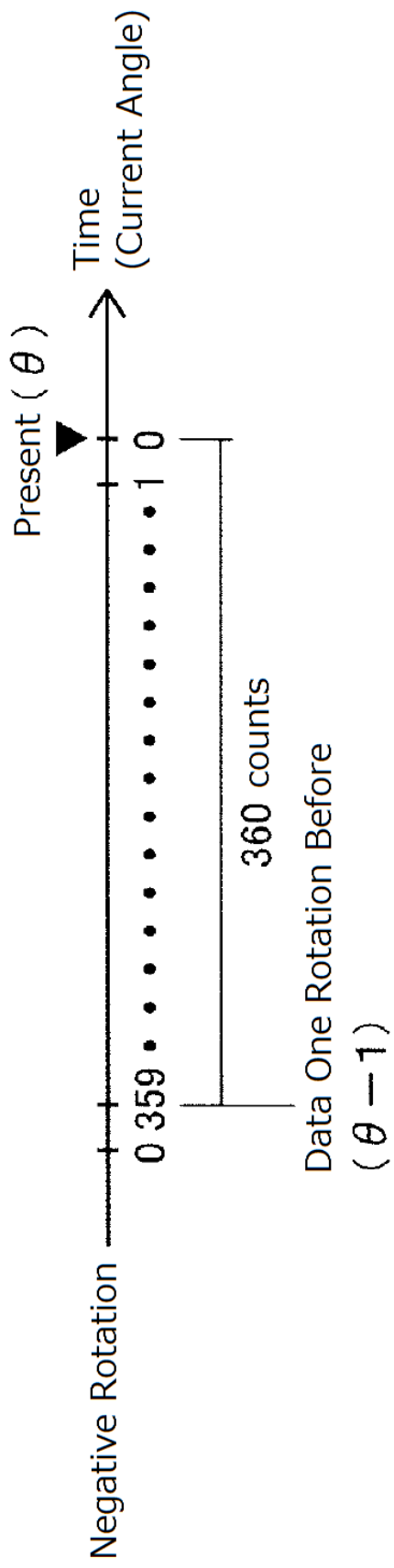


Fig. 6

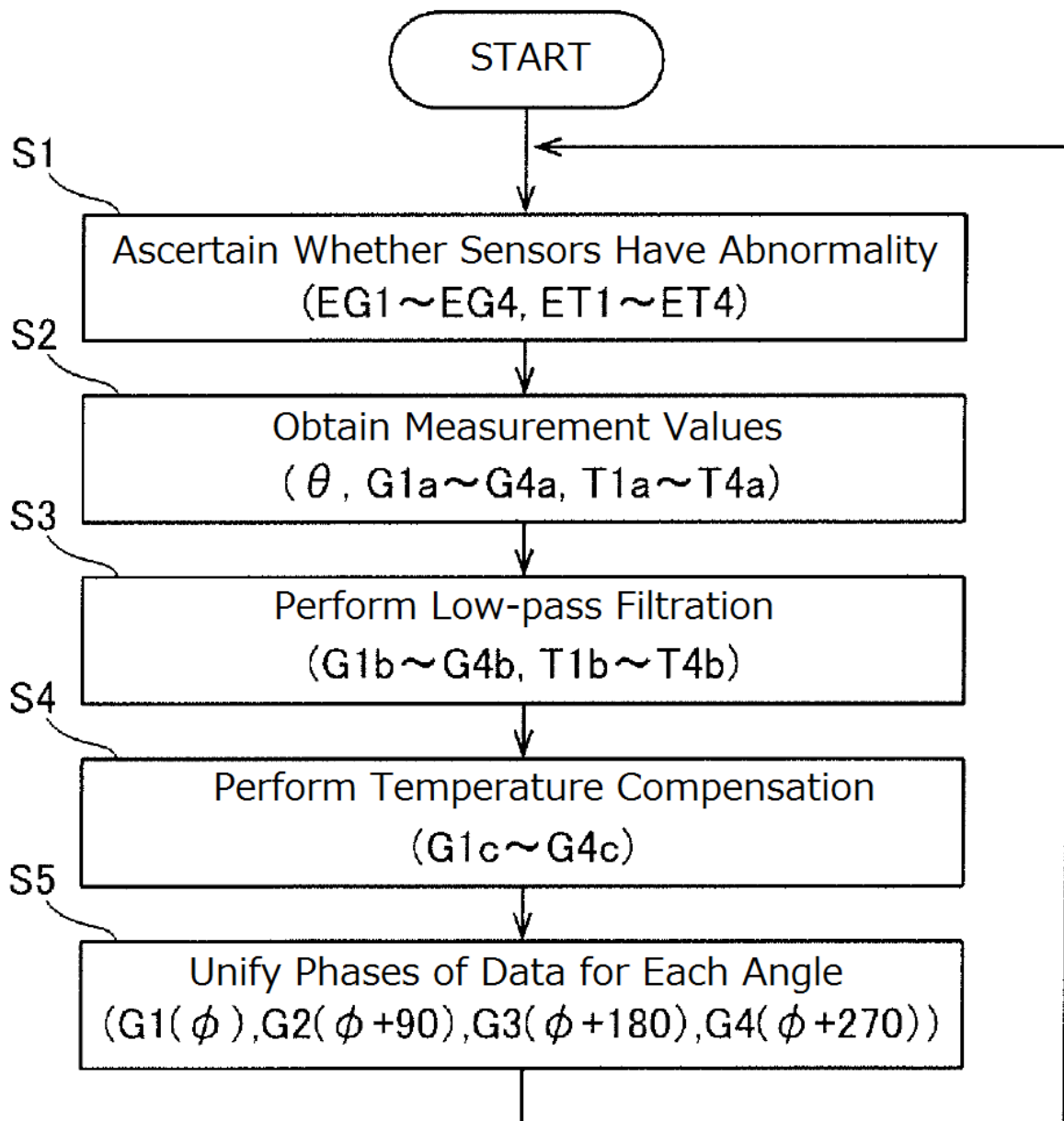
Measurement Flow

Fig. 7

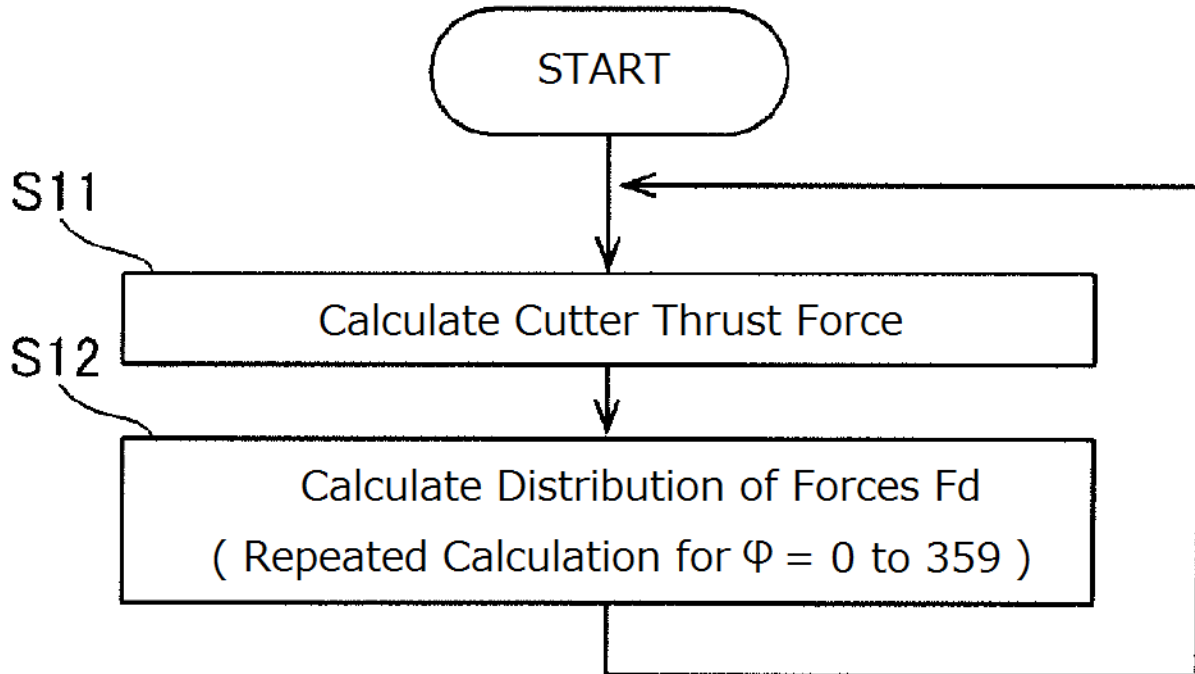
Operation Flow

Fig. 8

Calculation Flow of Cutter Thrust Force (Subroutine)

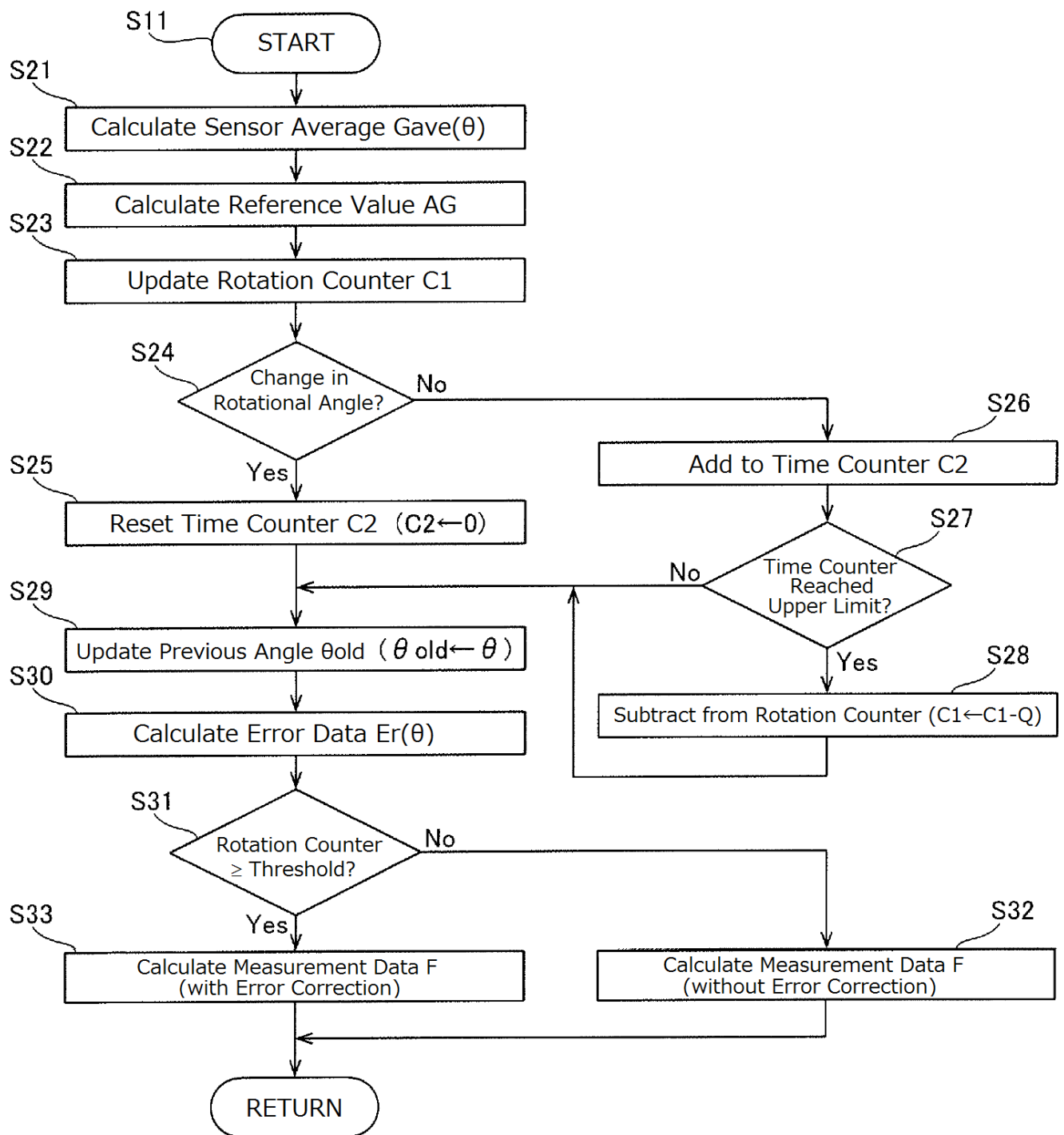


Fig. 9

Example of Processing by Data Processing Device
(Calculation of Measurement Data of Cutter Thrust Force)

	Time(sec)	θ	C1	C2	Cutter Thrust Force (etc.)
	0	0	0	0	
Rotation ($ \theta_{old} - \theta > 0$)	1	1	1	0	$F = K \times \text{Gave}(\theta)$: No Correction
	$\vdots$	$\vdots$	$\vdots$	$\vdots$	
	360	0	360	0	$F = K \times \{\text{Gave}(\theta) - \text{Er}(\theta)\}$: Correction
	$\vdots$	$\vdots$	$\vdots$	$\vdots$	
	720	0	720	0	C1 Reaches Upper Limit (720)
	721	1	720	0	
	$\vdots$	$\vdots$	$\vdots$	$\vdots$	
No Change in Angle ($ \theta_{old} - \theta = 0$)	T0	N	720	0	
	T1	N	720	1	C2 Count Up
	T2	N	720	2	
	$\vdots$	$\vdots$	$\vdots$	$\vdots$	
Determine Rotation has been Stopped	T9	N	720	9	
	T10	N	660	10	C2 Reaches Upper Limit (10), Subtraction from C1 (-60)
	U1	N	600	10	
	U2	N	540	10	
	U3	N	480	10	
	U4	N	420	10	
Stop-standby Time Elapsed	U5	N	360	10	
	U6	N	300	10	
	U7	N	240	10	
	U8	N	180	10	$F = K \times \text{Gave}(\theta)$: No Correction
	U9	N	120	10	
	U10	N	60	10	
	U11	N	0	10	
	U12	N	0	10	C1=0 (C1<0)
	U13	N	0	10	
	$\vdots$	$\vdots$	$\vdots$	$\vdots$	
Rotation	V1	N+1	1	0	C2=0

Fig. 10

Cutter Thrust Force Calculated from Jack Thrust Force

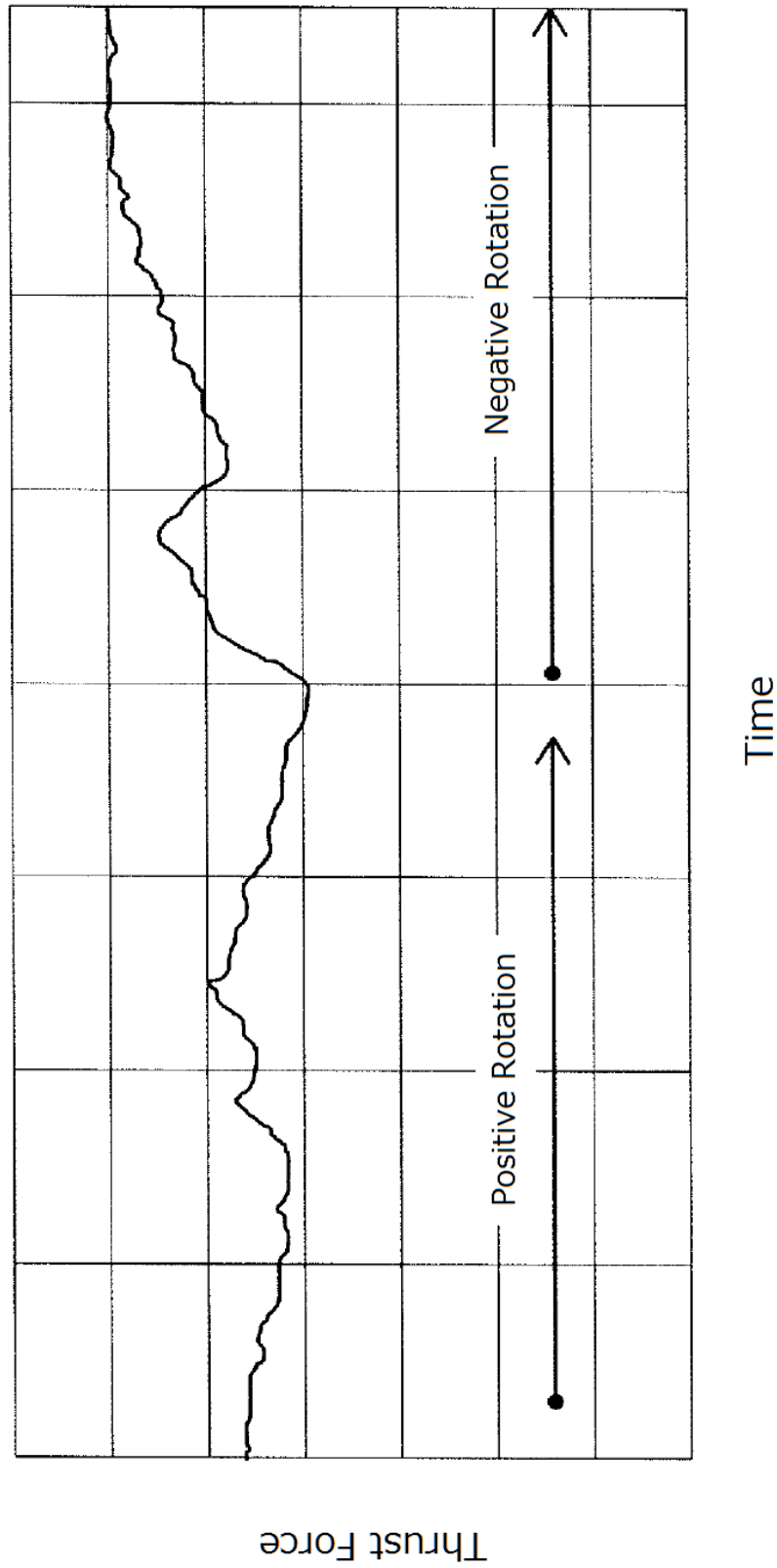


Fig. 11

Average Value of Strain Measurement Values of (Four) Cutter Columns

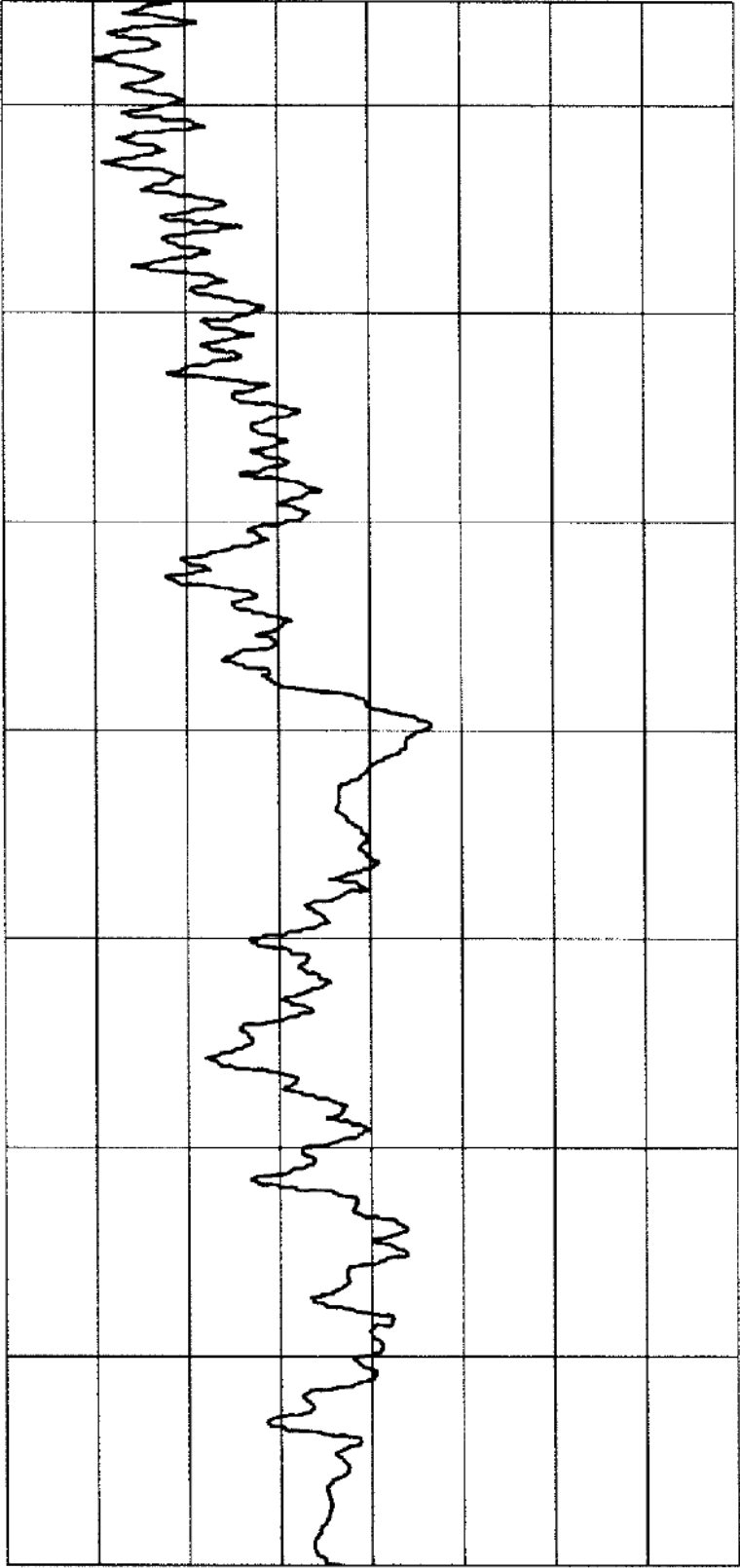


Fig. 12

Comparison between Thrust Force and Strain

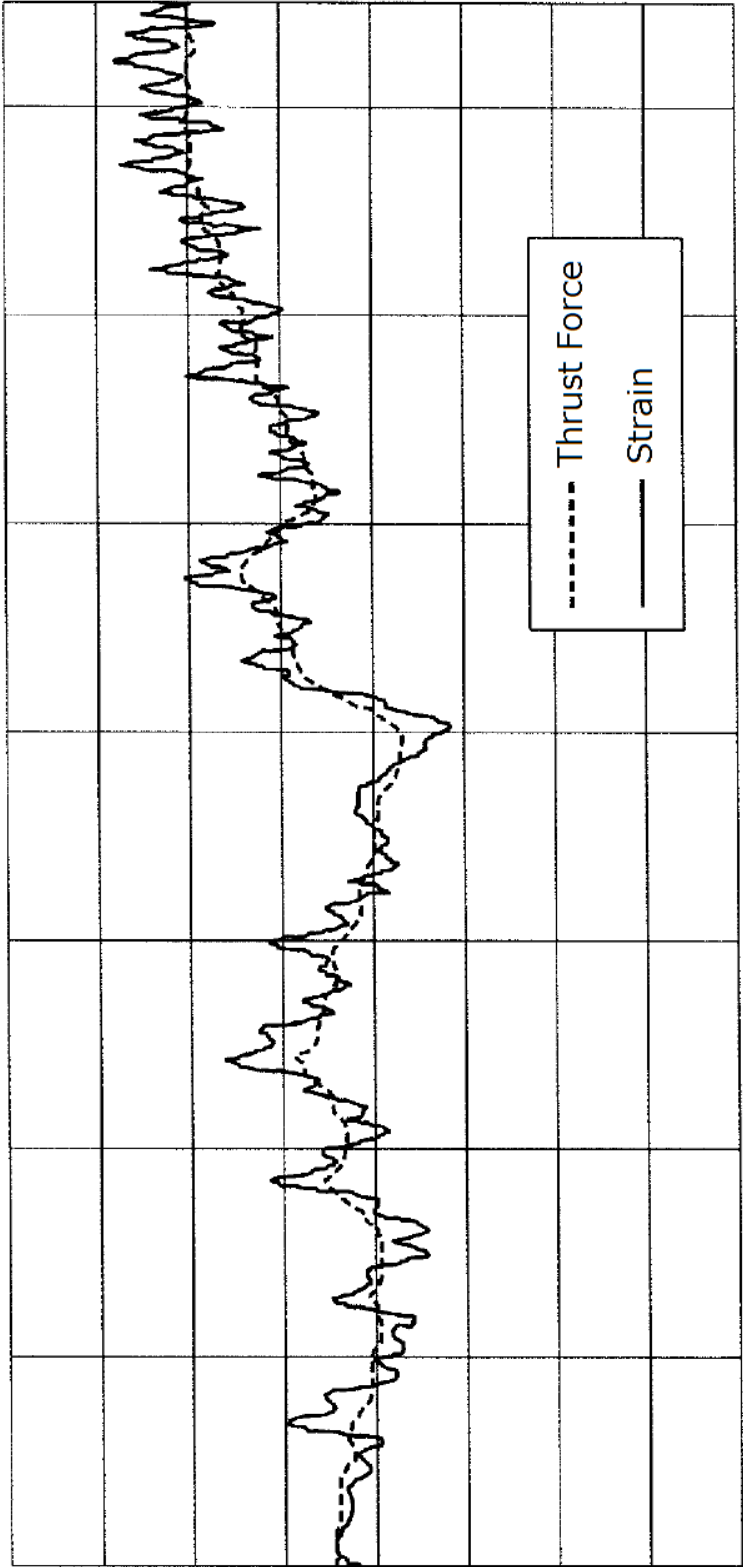


Fig. 13

Relationship between Strain and Rotational Angle (Cutter Position)

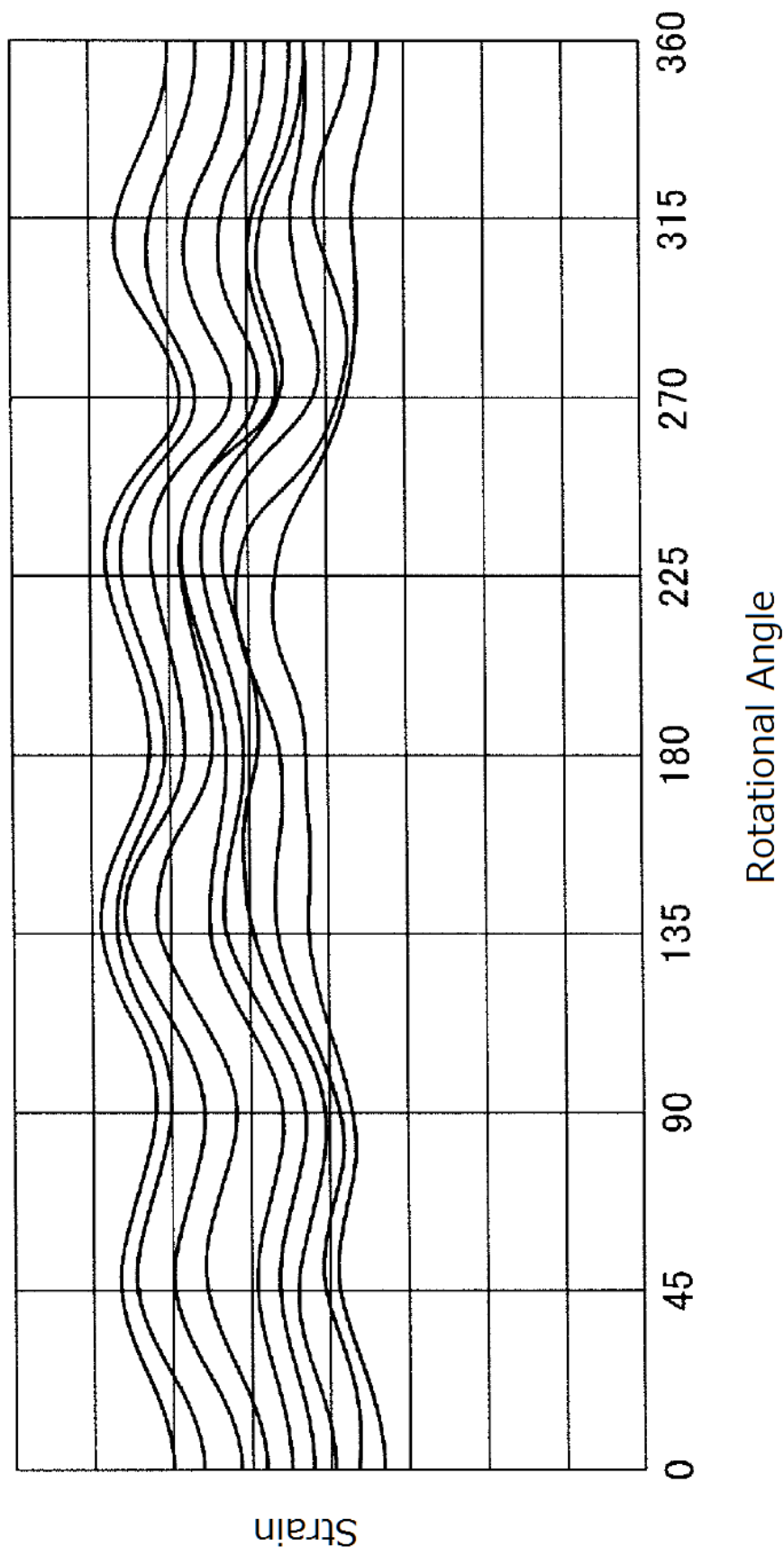


Fig. 14

Comparison between Thrust Force and Error-corrected Strain

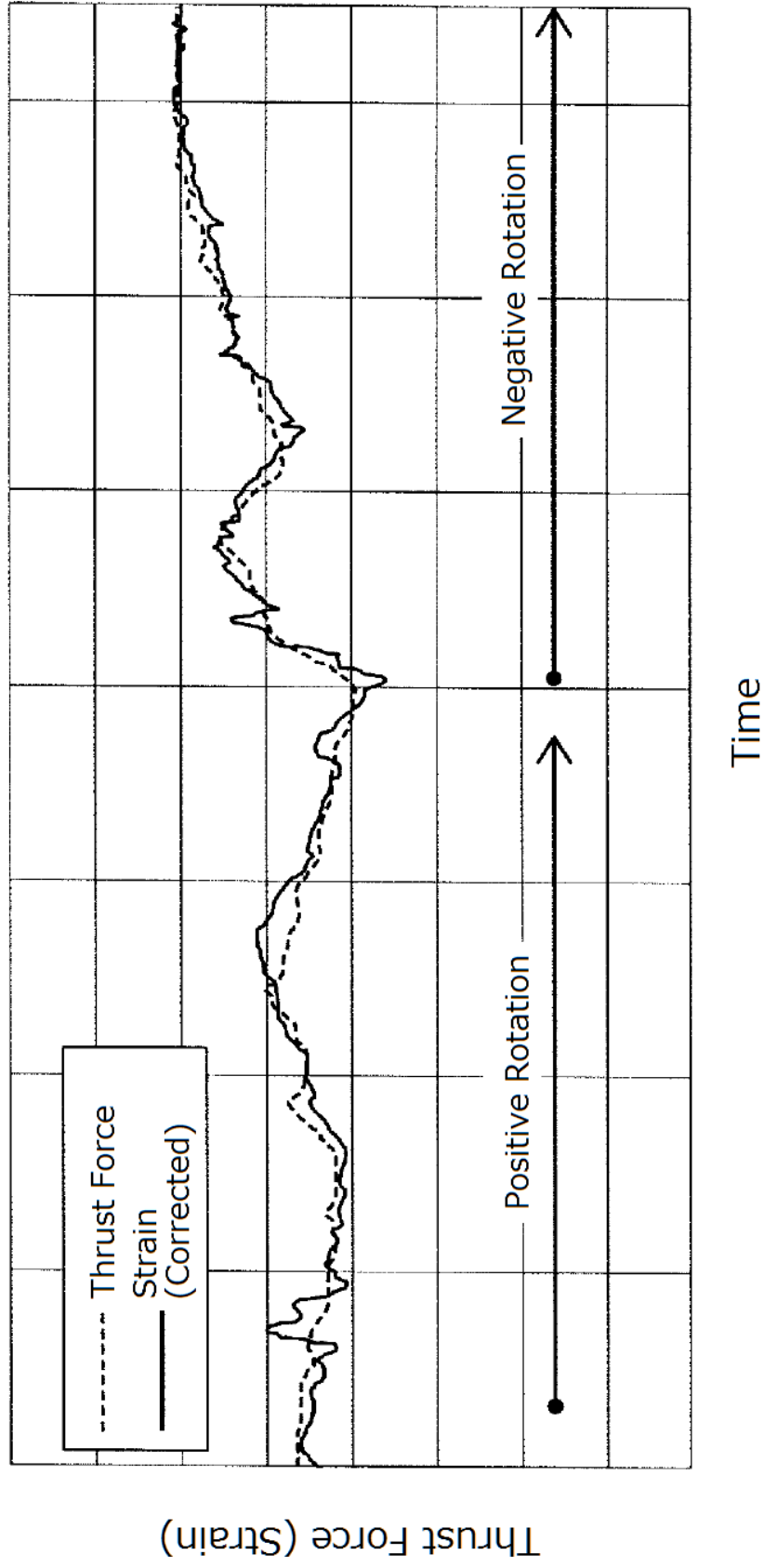


Fig. 15

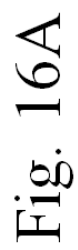


Fig. 16B

Second Variation

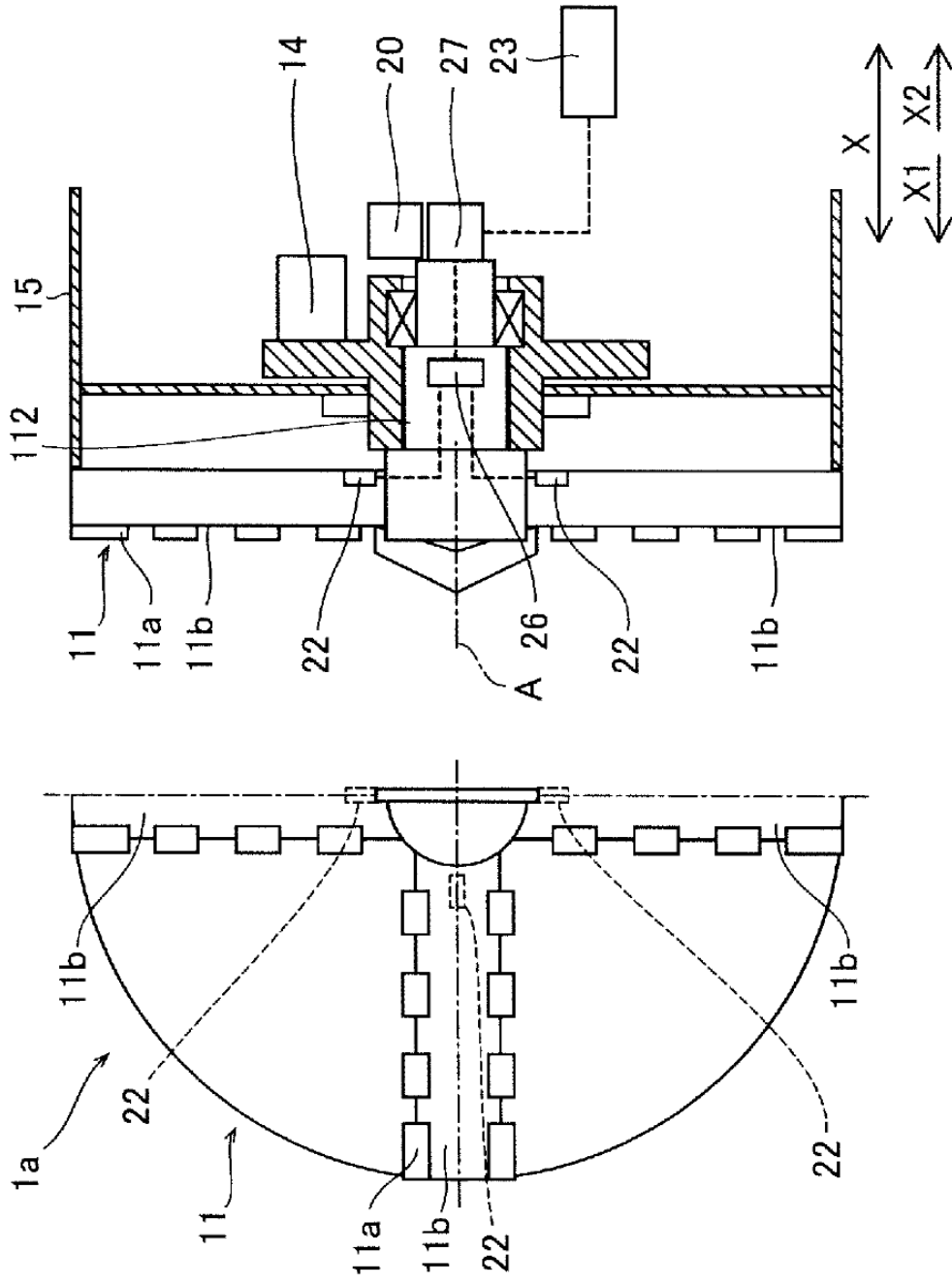


Fig. 17A

Fig. 17B