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6 ~ Component Balance SN0651 Calibration Report for

UNIVERSITY OF SURREY

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University of Surrey
6 ~ Component Balance SN0651 Calibration Report

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1.0 INTRODUCTION

The Aerotech 6 ~ Component Internal Balance is specifically designed to measure the aerodynamic loads on a model during wind tunnel testing. The design principles have evolved from many years experience in the design and manufacture of highly accurate and rugged multi-component internal Strain Gauged Balances for use in high speed tunnels for the Aerospace industry. As such the designs, methods of manufacture and chosen materials have been well tested and proven in extreme conditions.

The Balance is of one-piece construction and is equipped with six strain gauged bridges, each dedicated to the measurement of one aerodynamic component alone.

Figure 1 shows a photograph of the Balance. The Earth mounting face bolts directly to a support structure and the model attaches to the Live mounting face of the Balance. The six aerodynamic components Lift, Pitching moment, Drag, Side Force, Yawing moment and Rolling moment which act upon the model are thus measured by the Balance.

Figure 1: 6 ~ Component Balance

The Balance was commissioned and calibrated by Aerodynamic Test Equipment Ltd (ATE-Ltd).

A 6 channel Signal Conditioning Unit is mounted on the rear of the Balance to provide a digital, high resolution signal for each channel. Communication to the data acquisition system is via RS485 serial communication and specific software is used to read the Balance signals.

This report provides the user with important information which is required for the safe and correct operation of the Internal Balance. It includes a summary of the calibration analysis and the calibration matrix of coefficients applicable to the device supplied. Photographs and drawings of the Balance are presented and referred to within the text. It is recommended that this document is read by all personnel associated with the testing facility and that it is kept in a safe place for future reference.

2.0 CALIBRATION SUMMARY

2.1 GENERAL DESCRIPTION

The purpose of a full Balance calibration is the accumulation of sufficient data to realistically simulate the loads that the Balance will experience during testing. This data is then analysed to produce an equation for each aerodynamic component to predict the aerodynamic load from the given outputs of the Balance. The effect of using this equation (or coefficients arranged in matrix form), is not only to convert the electrical outputs from the Balance into Engineering units (kg, kgm or N, Nm) but also to remove the effects of interactions from all components into all other components.

During the calibration process the Balance is loaded to the maximum design loads in each component. The ATE-Ltd in-house Balance Calibration Analysis Programme performs a multiple linear regression on all of the data points collected during the calibration. The Balance outputs are all analysed as the independent variables against the applied loads to generate the coefficients for each aerodynamic component. The Multiple Linear Regression algorithm in the analysis programme minimises the error by fitting the "best fit line" to all the data points and generates an expression that describes the applied load in terms of all the measured values and relevant interactions between them.

Having determined the matrix coefficients, all raw data is then re-calculated through the coefficients to produce a "residual" for each data point. (Residual error is the difference between the actual applied load during calibration and that calculated from the raw data). The Root Mean Square (RMS) Residual (representing 1 Standard Deviation or 1 Sigma) of the distribution of the residual values is calculated. This is also equivalent to the Standard Error in engineering units for that axis. 1 Sigma represents a confidence level in the results of approximately 68%, and is the normal value that is quoted by ATE-Ltd. Having calculated the Standard Error as a load, it is then expressed as a percentage of the "full scale deflection" (full scale calibration load range) for that component.

2.2 SIGN CONVENTION

The standard sign convention for the Balance is shown in sketch SK26026-18 in section 7 of this report. Lift (Fz) is the force in the Z axis and is configured vertically upwards as positive. Pitching Moment (My) is the rotational loading about the Y axis moment centre of resolution - positive being nose upwards. Positive Drag (Fx) is the force in the X axis, down the tunnel in the direction of wind. Side force (Fy) is the force perpendicular to the direction of travel - positive being to right when looking into wind. Yawing moment (Mz) is the rotational loading about the Z axis moment centre of resolution - positive being counter-clockwise when looking down on the Balance in plan view. Rolling moment (Mx) is the rotational loading about the X axis - positive being left hand side downwards when looking into wind.

2.3 LOAD RANGE

The following table shows the Balance load ranges:

Component		**Load Range**	
Fz	Lift	-650 to +450	N
My	Pitch Moment	-40 to +80	Nm
Fx	Drag	0 to +200	N
Fy	Side Force	±180	N
Mz	Yaw Moment	±10	Nm
Mx	Roll Moment	±70	Nm

Note: The above Lift load ranges include the aerodynamic Lift and the mass of the model and associated equipment.

In addition to the load ranges defined for each component an overload capacity exists where a further 25% of each load may be applied to the Balance without detrimental effects. Whilst it is not recommended that the overload facility be used regularly, sufficient safety factors exist to prevent damage under these conditions.

2.4 DEFLECTION DATA

Balance deflections under calibration loads were measured and approximate linear and angular stiffness figures of the Balance are shown below for reference only. These values are for the Balance only, mounted on a rigid calibration structure. Subsequent system deflections are likely to be greater than stated here due to the stiffness of the user's earth and model attachments.

Component		Calibration Load	Measured Deflection	Stiffness
Fz	Lift	68kg	0.045mm	1.5×10^7 N/m
My	Pitch Moment	8kgm	0.07°	6.4×10^4 Nm/rad
Fx	Drag	20kg	0.05mm	3.9×10^6 N/m
Fy	Side Force	18kg	0.045mm	3.9×10^6 N/m
Mz	Yaw Moment	1.2kgm	0.05°	1.4×10^4 Nm/rad
Mx	Roll Moment	7.5kgm	0.11°	3.8×10^4 Nm/rad

2.5 OUTPUT DATA FORMAT

The electrical interface is described in section 4.2 and the output data from the Balance is direct from the signal conditioning units. When communication has been established with the signal conditioning units the data returned is presented as a percentage of the full scale input to the signal conditioning units. For ease of data evaluation ATE-Ltd multiply the percentage by a factor of 2000 (yielding 'counts') prior to logging the data. Subsequent data from the Balance should be treated in an identical manner prior to applying the calibration matrix of coefficients.

2.6 CALIBRATION RESULTS

The calibration matrix is stored as a separate file on the Wind Tunnel Control System (WTCS) computer. This matrix converts the digital output signals to kg and kgm loads. Below the matrix of coefficients is a summary of the calibration analysis. The section labelled *[Confidence]* contains the number of data points analysed for each component, the RMS Residual (*RMSResid*), the maximum applied load (*MaxApp*) and the Standard Error expressed as a percentage of the full scale calibration load range (*StdPerc*).

Balance Serial Number: SN0651 *Matrix file: Balance.mat*

Title=SURREY UNIVERSITY 6 ~ COMPONENT BALANCE CALIBRATION SN0651.WB3

Components=	Lift	Pitch	Drag	Side Force	Yaw	Roll
[Coefficients]						
A1	0.00153627	-2.10185E-07	2.16707E-07	2.39108E-07	-1.6073E-08	6.35496E-08
A2	-4.41738E-06	0.000331981	-6.76938E-06	9.64339E-07	-3.09347E-07	7.53032E-07
A3	5.29037E-07	-1.82826E-06	0.000442851	-9.23272E-06	9.82927E-08	7.3123E-07
A4	3.55637E-06	-1.43433E-06	2.55413E-06	0.00049948	7.60903E-07	1.35755E-06
A5	-1.89099E-06	-2.72315E-06	-1.15882E-05	4.92182E-06	4.15295E-05	-8.08015E-07
A6	2.27442E-05	-1.78546E-06	-1.43942E-06	4.85001E-06	5.56457E-06	0.00024386
A1^2	-1.06731E-12	2.99405E-12	-3.35146E-12	-1.5321E-12	-1.19539E-13	-1.22816E-13
A2^2	-1.16964E-11	-1.713E-11	4.52854E-11	2.48699E-12	6.98323E-13	-4.77847E-12
A3^2	1.4902E-11	-7.43627E-13	9.95294E-12	-2.06573E-11	8.92309E-13	2.0363E-12
A4^2	2.64892E-11	1.3638E-12	-1.96091E-11	9.52221E-13	2.87871E-12	1.09021E-12
A5^2	1.57586E-11	3.33382E-12	5.45154E-12	6.44074E-12	3.7326E-15	-2.45838E-14
A6^2	1.3338E-11	7.68238E-12	-1.62433E-11	3.31301E-12	8.86888E-13	-1.23042E-12
A1A2	8.49449E-12	-7.89723E-13	3.17491E-11	-1.19954E-11	-8.04516E-13	1.94254E-12
A1A3	-8.31364E-12	7.12884E-13	3.19067E-11	-8.16547E-13	3.24462E-13	1.58035E-12
A1A4	-1.0199E-11	-6.44982E-12	-2.17579E-12	1.99802E-11	4.81814E-13	-1.05531E-12
A1A5	-1.77445E-11	-6.39795E-12	-2.10219E-12	7.27584E-12	3.54965E-12	6.31091E-13
A1A6	-1.42293E-11	2.25791E-12	-1.3644E-11	-1.91881E-12	2.88367E-12	-1.88639E-11
A2A3	-1.14695E-11	-2.03969E-12	-4.8507E-12	2.62353E-12	-2.38434E-14	1.85626E-12
A2A4	1.31911E-12	-9.47376E-12	5.9438E-12	-5.07258E-12	-6.01833E-12	8.32166E-13
A2A5	-5.58312E-12	-9.5696E-12	7.35842E-12	-2.51084E-10	-1.28651E-12	5.24875E-12
A2A6	-2.09829E-12	1.15483E-12	4.59274E-13	-3.0957E-11	-2.27639E-12	6.84079E-12
A3A4	8.15624E-13	-4.1023E-13	1.08716E-11	-1.27252E-11	1.93995E-13	-5.03133E-13
A3A5	-1.11149E-15	3.30871E-12	-7.75259E-12	7.33812E-12	9.268E-13	1.53446E-14
A3A6	2.61999E-12	1.24864E-12	4.06255E-12	-3.08607E-12	-6.34232E-12	-3.8337E-12
A4A5	7.23908E-12	4.19918E-12	-1.52667E-11	-2.03918E-12	2.14116E-12	-4.24474E-13
A4A6	1.99278E-11	2.84306E-12	-2.2316E-12	2.75552E-12	2.10941E-13	3.51859E-12
A5A6	4.97599E-11	-1.01577E-12	-2.00201E-10	-4.81379E-12	8.2118E-13	-2.43731E-12
[Confidence]						
Points=	487	487	487	487	487	487
RMSResid=	0.00831756	0.002404	0.00591734	0.013506	0.000818383	0.00158099
MaxApp=	94.0675	8.4471	21.1429	19.2276	1.62187	7.52947
StdPerc=	0.0122317	0.03005	0.0295867	0.0750334	0.0681986	0.0210798

Calibration performed during 17th – 28th May 2010

3.0 MATHEMATICAL INTERPRETATION OF CALIBRATION COEFFICIENTS

The general equation for each component in a 6 ~ Component Balance is as follows:

$$
\begin{aligned}
L(n) = \; & R_1.X_{n1} + R_2.X_{n2} + R_3.X_{n3} + R_4.X_{n4} + R_5.X_{n5} + R_6.X_{n6} + \\
& R_{11}.X_{n11} + R_{22}.X_{n22} + R_{33}.X_{n33} + R_{44}.X_{n44} + R_{55}.X_{n55} + R_{66}.X_{n66} + \\
& R_{12}.X_{n12} + R_{13}.X_{n13} + R_{14}.X_{n14} + R_{15}.X_{n15} + R_{16}.X_{n16} \\
& R_{23}.X_{n23} + R_{24}.X_{n24} + R_{25}.X_{n25} + R_{26}.X_{n26} \\
& R_{34}.X_{n34} + R_{35}.X_{n35} + R_{36}.X_{n36} \\
& R_{45}.X_{n45} + R_{45}.X_{n46} \\
& R_{56}.X_{n56}
\end{aligned}
$$

Where n = 1 to 6:

1	=	Lift (or Normal Force)
2	=	Pitching Moment
3	=	Drag (or Axial Force)
4	=	Side Force
5	=	Yawing Moment
6	=	Rolling Moment

L(n) is the calculated aerodynamic load, kg or kgm.
R_n is the output signal for the relevant component.
X_{nm} is a calibration coefficient within the overall equation.
m specifies the axis or axes from which the coefficient was derived.

The manipulation of the coefficients to determine the final aerodynamic load may be by use of an equation, or by matrix manipulation. For ease of presentation of data, we supply the coefficients in an array or matrix form. The full calibration matrix for a 6 ~ Component Balance consists of 6 columns and 27 rows and is shown on the following page. The 27 coefficients in each column are those which are required for the full determination of one aerodynamic load.

Full Matrix of Calibration Coefficients

$$
\begin{vmatrix} R_1 \\ R_2 \\ R_3 \\ R_4 \\ R_5 \\ R_6 \\ R_{11} \\ R_{22} \\ R_{33} \\ R_{44} \\ R_{55} \\ R_{66} \\ R_{12} \\ R_{13} \\ R_{14} \\ R_{15} \\ R_{16} \\ R_{23} \\ R_{24} \\ R_{25} \\ R_{26} \\ R_{34} \\ R_{35} \\ R_{36} \\ R_{45} \\ R_{46} \\ R_{56} \end{vmatrix}
*
\begin{vmatrix}
X_{11} & X_{21} & X_{31} & X_{41} & X_{51} & X_{61} \\
X_{12} & X_{22} & X_{32} & X_{42} & X_{52} & X_{62} \\
X_{13} & X_{23} & X_{33} & X_{43} & X_{53} & X_{63} \\
X_{14} & X_{24} & X_{34} & X_{44} & X_{54} & X_{64} \\
X_{15} & X_{25} & X_{35} & X_{45} & X_{55} & X_{65} \\
X_{16} & X_{26} & X_{36} & X_{46} & X_{56} & X_{66} \\
X_{111} & X_{211} & X_{311} & X_{411} & X_{511} & X_{611} \\
X_{122} & X_{222} & X_{322} & X_{422} & X_{522} & X_{622} \\
X_{133} & X_{233} & X_{333} & X_{433} & X_{533} & X_{633} \\
X_{144} & X_{244} & X_{344} & X_{444} & X_{544} & X_{644} \\
X_{155} & X_{255} & X_{355} & X_{455} & X_{555} & X_{655} \\
X_{166} & X_{266} & X_{366} & X_{466} & X_{566} & X_{666} \\
X_{112} & X_{212} & X_{312} & X_{412} & X_{512} & X_{612} \\
X_{113} & X_{213} & X_{313} & X_{413} & X_{513} & X_{613} \\
X_{114} & X_{214} & X_{314} & X_{414} & X_{514} & X_{614} \\
X_{115} & X_{215} & X_{315} & X_{415} & X_{515} & X_{615} \\
X_{116} & X_{216} & X_{316} & X_{416} & X_{516} & X_{616} \\
X_{123} & X_{223} & X_{323} & X_{423} & X_{523} & X_{623} \\
X_{124} & X_{224} & X_{324} & X_{424} & X_{524} & X_{624} \\
X_{125} & X_{225} & X_{325} & X_{425} & X_{525} & X_{625} \\
X_{126} & X_{226} & X_{326} & X_{426} & X_{526} & X_{626} \\
X_{134} & X_{234} & X_{334} & X_{434} & X_{534} & X_{634} \\
X_{135} & X_{235} & X_{335} & X_{435} & X_{535} & X_{635} \\
X_{136} & X_{236} & X_{336} & X_{436} & X_{536} & X_{636} \\
X_{145} & X_{245} & X_{345} & X_{445} & X_{545} & X_{645} \\
X_{146} & X_{246} & X_{346} & X_{446} & X_{546} & X_{646} \\
X_{156} & X_{256} & X_{356} & X_{456} & X_{556} & X_{656}
\end{vmatrix}
=
\begin{vmatrix} L_1 \\ L_2 \\ L_3 \\ L_4 \\ L_5 \\ L_6 \end{vmatrix}
$$

R1 to R66 are the signal values, signal values squared and the cross product of the relevant signals. X11 to X666 are the matrix coefficients, and L1 to L6 are the calculated aerodynamic loads in kg and kgm.

The following page shows an example calibration matrix for a 6 ~ Component Balance. This matrix consists of 6 columns and 27 rows, but some of these terms in the overall matrix may be determined as zero or insignificant.

The first column beginning 308.4700, -1.9464, 0.5399, etc, contains all the coefficients to determine, in this case, the Lift in kg. Similarly, the second column contains all the coefficients for Pitching Moment, the third column for Drag, the fourth for Side Force, fifth for Yawing Moment and sixth for Rolling Moment.

To the left hand side of the full matrix is a column of one or two digit numbers. These refer to the signal output channel. The signal channels are numbered 1-6 (1 = Lift, 2 = Pitch, 3 = Drag, 4 = Side, 5 = Yaw, 6 = Roll).

The values in this example are a real set of calibration coefficients. However, depending on many factors the magnitude and ratio of the coefficients of different Balances vary greatly. These factors include, but are not limited to:

i. Balance Load Cell Output signal range :
- Raw millivolt signals
- Amplified Volt signals
- Digital outputs and full scale resolution
- Outputs normalised with respect to excitation voltage

ii. Units of Final Aerodynamic forces :
- kg, kgm
- N, Nm
- lbf, lbf ins

iii. Ratio of full scale design loads of one component to another.

EXAMPLE CALIBRATION MATRIX

	COLUMN 1	COLUMN 2	COLUMN 3	COLUMN 4	COLUMN 5	COLUMN 6	
1	308.4700	0.1314	1.1547	-0.5738	-0.0182	-0.2350	SECTION 1 PRIMARY TERMS
2	-1.9464	25.1754	-1.7114	0.0484	-0.0755	-0.1770	
3	0.5399	-0.0030	104.5970	-0.0317	0.0342	0.0058	
4	-3.2453	0.0187	0.1605	147.6760	-0.1640	0.0617	
5	-0.1077	-0.2918	-1.1421	0.6351	13.4650	-0.0230	
6	1.9420	-0.3228	-0.6459	-1.5732	0.0195	10.7415	
11	0.0500	-0.0006	0.0433	0.0147	-0.0011	-0.0038	SECTION 2 SQUARED TERMS
22	0.0456	0	-0.0228	0.0031	-0.0020	-0.0059	
33	0.0050	-0.0011	-0.0008	-0.0189	-0.0002	-0.0008	
44	-0.0074	-0.0004	0.0134	-0.0155	0.0007	-0.0023	
55	0.0076	-0.0013	0.0034	-0.0270	0.0015	-0.0039	
66	0.0319	-0.0007	-0.0331	-0.0229	-0.0002	0.0013	
12	-0.0193	-0.0046	-0.0876	0.0180	-0.0014	-0.0030	SECTION 3 CROSS-PRODUCT TERMS
13	-0.0076	-0.0010	0.0592	-0.0002	0.0002	-0.0001	
14	-0.0004	-0.0002	-0.0003	0.0038	-0.0009	-0.0086	
15	0.0330	0.0004	0.0030	-0.0064	0	-0.0097	
16	0.0124	0.0002	0.0025	-0.0985	-0.0026	-0.0019	
23	0.0192	0.0006	0.0002	0	0	-0.0003	
24	0.0349	0.0015	0.0004	-0.0279	0.0005	-0.0121	
25	0.0618	0.0023	-0.0002	-0.0209	-0.0006	-0.0087	
26	-0.0009	-0.0010	0.0019	-0.0528	-0.0046	-0.0050	
34	-0.0036	-0.0001	-0.0015	-0.0045	-0.0009	0	
35	-0.0031	-0.0004	-0.0011	0.0234	0.0007	0	
36	0.0001	0.0001	0.0001	0.0034	0.0001	-0.0004	
45	-0.0155	-0.0003	-0.0368	-0.0417	-0.0003	-0.0056	
46	0.0393	0.0014	-0.64	-0.0046	0.0001	-0.0007	
56	0.0320	0.0006	-0.0510	-0.0071	-0.0002	0.0003	

Notes on the above matrix:

1. The primary calibration coefficient for each component is shown as the largest value coefficient in each column in section 1 (i.e. the “leading diagonal”).
2. Section 1 interactions are significantly smaller than the primary coefficients.
3. Squared and Cross Product terms look very small, but they are multiplied by larger output signal values (ie Lift^2, Lift * Pitch or Side Force * Drag outputs, etc).

4.0 INSTALLATION DETAILS

4.1 MECHANICAL INTERFACE

The Balance is fitted with an Earth Mounting Plate which is a horizontal surface at the base of the Balance and interfaces to the support structure. Earth and Live Covers surround the critical elements of the Balance and the horizontal end face of the Live Cover at the top of the Balance is the mating surface for the model. The Balance should be accurately levelled during installation in all axes to replicate the calibration setup as close as possible.

The Earth and Live mounting faces are parallel to each other and incorporate precision location features and tapped fixing holes as shown in SK26026-18 in section 7. The Earth face is identical to the Live face of the Balance. For the Earth and Live mounting the Balance includes two Ø5mm (H7) x 10 deep dowel holes for accurate location and four M6 x 10 deep tapped holes for rigid attachment. The tightening torque for the attachments should not exceed 20Nm and the Live Cover must be supported when tightening fixings. Extreme care is necessary to avoid overloading the Balance Yaw axis.

It is essential that no model components contact the Earth Plate, Earth Cover or Signal Conditioning Unit, as this will obstruct the small deflection that takes place within the Balance as it is loaded. Similarly, any cables that pass from earth to the model must be carefully routed with adequate compliance to avoid restricting the Balance operation.

4.2 ELECTRICAL INTERFACE

During the design phase of the Balance the user’s load range is used to calculate the stresses and hence the electrical sensitivities for each aerodynamic component. Each bridge is individually temperature compensated from 0 to 60℃ during the strain gauging process and cycled to minimise the effects of changes in temperature during operation of the Balance.

Within the Signal Conditioning box, each bridge has its own dedicated signal conditioning unit which provides excitation voltage, performs signal conditioning and converts the outputs from analogue to digital for transmission on RS485 serial communication.

A Lemo fixed socket connector EGG.1B.305.CLM is fitted on the underside of the Signal Conditioning Unit and connection is made to the data acquisition system using the supplied lead.

For reference, the communication station numbers which identify each signal conditioning unit are as detailed in the following table.

Component	**Station Number**
Fz Lift	11
My Pitch Moment	12
Fx Drag	13
Fy Side Force	14
Mz Yaw Moment	15
Mx Roll Moment	16

The Balance and Signal Conditioning Unit were calibrated as a complete system and therefore no attempt should be made to open the Signal Conditioning box since this will invalidate the calibration.

The approximate full scale counts based upon the Load Ranges in section 2.3 are as follows:

Component	**Full Scale Counts**
Fz Lift	43100
My Pitch Moment	24600
Fx Drag	46000
Fy Side Force	36800
Mz Yaw Moment	24600
Mx Roll Moment	29100

5.0 TRANSPORTATION AND STORAGE CASE

The Balance is supplied in a case that is suitable for transportation and storage. Appropriate care should be taken when removing the Balance to avoid damage to the Signal Conditioning Unit. The Balance should be supported and the case tilted to allow easy removal.

Figure 3 shows a photograph of the Balance fitted in its transportation case. For reference, the Balance weighs 6.5kg.

Figure 3: Balance Fitted in Transportation Case

6.0 CAUTIONARY NOTES

As with all sensitive instrumentation equipment certain measures should be taken to ensure that the Balance is not damaged. Failure to observe the cautionary notes listed here could result in a degradation of Balance accuracy.

In addition to the load ranges defined for each component an overload capacity exists where a further 25% of each load may be applied to the Balance without detrimental effects. Whilst it is not recommended that the overload facility is used regularly, sufficient safety factors exist to prevent damage during handling, model rigging or unforeseen accidents. Shock loading of the Balance should be avoided.

Further protection is given to the Balance by a rigid Earth plate, Earth Cover and Live Cover which surround the Balance critical elements. These items must not be tampered with or removed since they are set up on the Balance prior to the calibration. Subsequent removal could cause damage to the load sensing components and will invalidate the calibration.

The Balance should be kept in a clean environment free from dust and dirt. It should not be exposed to moisture or cleaned using any solvent or solution. The external faces of the Balance may be wiped with a clean dry cloth when necessary. When the Balance is not in use always store and transport the Balance in the case that the Balance was originally supplied in.

During handling and installation, the Balance should be supported by its Earth Plate or Live cover. When tightening fixing screws always ensure that the Balance is supported at the attachment point to avoid torsional loading. The Balance signals should be monitored at all times during installation and usage to ensure that excessive loads are not encountered. Care should also be taken to avoid any load being applied to the Signal Conditioning Unit or electrical cable connections.

If any doubt arises regarding the handling, installation, usage or performance of the Balance contact ATE-Ltd.

7.0 SCHEMATIC DIAGRAMS

The following sketches are schematic diagrams showing the general arrangement of the equipment supplied. These diagrams are included for reference only and may not necessarily represent in exact detail what has been described in this report.

Sketch Number	Title
SK26026-18	Balance Configuration