RV SIKULIAQ ALIGNMENT AND ORTHOGONAL COORDINATE SURVEY

FINAL REPORT

March 5, 2016 Revision 2

Prepared By:

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Revision 1. 2/9/2014- Added Kongsberg MRU to Table 5, Revised Kongsberg MRU elevation Table 2 and Figure 3, Added Elevation of 20FT Draft mark to page 5.

Revision 2. 3/5/2016 – Resurveyed 9.1, 9.2 GPS and 10.3 GCGPS after relocation.

PROJECT OVERVIEW

Purpose

The purpose of this commentary is to summarize the procedures and analytical methods employed to perform the 3-D coordinate total station inspection that produced the data in this report for those unfamiliar with the equipment and process.

Dimensional data resulting from the inspection is included with the report.

General Comments- Tasks performed

This report summarizes data taken, analyzed and recorded by IMTEC Group, Ltd. from October 2011 through June, 2013.

The survey data included characterizing the vessel, locating and determining 3-D coordinates of benchmarks and features as outlined in Section 725 of ARRV Contract Specifications dated 18 March, 2009.

3-D Coordinate Measurement Equipment

A Sokkia NET 1200 enhanced electronic total station operated through a notebook computer running New River Kinematics Spatial Analyzer™ measurement and analysis software was utilized. This system measures 3-D spherical coordinates by recording an azimuth and zenith angle simultaneously with the near infrared distance coaxial with the telescope line of sight for each observation. Spatial Analyzer measurement and analysis software converts the spherical coordinate data to a Cartesian coordinate system that can be defined by the user. Measurements are made to either adhesive or kinematic targets that have a retro-reflective target face. Where practical, certain features were measured with the instrument in the “Reflectorless” targeting mode.

Temporary "benchmarks" or reference points were placed throughout the vessel as required to allow for re-locating the instrument to a new position or "Station" and tie all of the data to the common coordinate system for comparison.

The measuring system used for this final inspection report is one of several owned by The IMTEC Group, Ltd. The NET 1200 total stations, S/N 110350 and S/N 110554 were calibrated, traceable to N.I.S.T. and in accordance with A.N.S.I. Z-540-1, at the Sokkia USA Factory Service Center.

A Wyler CLINO 2000, Electronic Clinometer S/N M4474 was used the set the Pitch and Roll axis of the Granite Block.

Certificates of calibration for all instruments are kept on file in the IMTEC offices. Each test instrument had a current calibration sticker affixed to it at the time it was utilized for this project.

Reference Coordinate System

The following parameters were used to define the reference coordinate system for reporting the survey data:

The origin for the vessel coordinate system (0, 0, 0) is the center of the granite block. The X (+X) axis is positive forward, the Y (+Y) axis is positive starboard and the Z (+Z) axis is positive down towards the keel.

Measurement Procedure

Adhesive targets with retro reflective target face were used throughout the survey as temporary benchmarks for relocating the instrument to new stations. Kinematic (a target with a known offset) retro reflective targets such as the RT-50M swivel targets used to measure some of the features defining the specified elements to be reported. The RT-50M was also frequently used as a temporary benchmark. Where possible, a retro reflective surface target was used to eliminate any offsets.

3-D X, Y, Z coordinates, Post Processing

In some cases, the features or targets defining the elements required by the survey were made to a kinematic target with a known offset orthogonal to the vessel’s final reference coordinate system. After the each survey was complete, these offsets were applied to report the final X, Y, Z value of the element.

The pitch and roll values were processed mathematically in the Spatial Analyzer software. Backup data is provided with this report.

Data files

One measurement file was used to perform the survey.

All measurement files were backed up at the completion of a set of observations from a particular station and on a daily basis.

This vessel coordinate system was created from the initial characterization file.

Measurement Precision and Uncertainty

Region to Region, i.e., Origin to main mast features; BM, DGPS, etc.

$X \leq 5$ mm
$Y \leq 5$ mm
$Z \leq 5$ mm

Locally, i.e. EM302 TX to ADCP’s and Topas PS 18

X ≤ 2 mm
Y ≤ 2 mm
Z ≤ 2 mm

Antenna Survey-

X ≤ 30 mm
Y ≤ 30 mm
Z ≤ 30 mm

Angular precision is based on analysis of features measured and calculation of the mathematical relationship of these features.

The angular measurement precision of the NET1200 is < 1 arc second in azimuth and zenith. There can be some error introduced by targeting. Random and systematic errors can be introduced by the working environment.

The expected angular precision is analyzed to be:

Azimuth:	≤ 00° 00’ 30”
Pitch:	≤ 00° 01’ 00”
Roll:	≤ 00° 01’ 00”

PROJECT DATA

TABLE 1- BENCHMARKS WITH RESPECT TO GRANITE BLOCK, METERS				
ITEM	LOCATION	X	Y	Z
ORIGIN	GRANITE BLOCK	0.000	0.000	0.000
BM1	ON CENTER- MAIN MAST, AFT 1.4 M ABOVE 04 LEVEL	14.076	2.122	-15.228
BM2	01 LEVEL ON DECK STBD BASE OF AFT AFRAME	-23.782	5.271	-2.497
BM3	01 LEVEL AFT DECK STBD	-9.830	9.222	-2.387
BM4	01 LEVEL AFT DECK PORT	-9.830	-4.906	-2.393
BM5	ON CENTER FWD MAST, AFT 5.7 M ABOVE 01 LEVEL	50.105	2.121	-11.361
BM6	05 LEVEL STBD NEAR BASE OF ANTENNA 2.6	27.878	6.923	-16.579
BM7	05 LEVEL PORT NEAR BASE OF ANTENNA 2.5	27.879	-2.644	-16.597
BM8	02 LEVEL, STBD MARKS AFT OF CENTEBOARD	19.193	9.601	-8.525
BM9	02 LEVEL, STBD MARKS FWD OF CENTEBOARD	22.300	9.601	-8.516
BM10	02 LEVEL, PORT MARKS FWD OF CENTEBOARD	22.300	-5.627	-8.488
BM11	02 LEVEL, PORT MARKS AFT OF CENTEBOARD	19.192	-5.626	-8.506
BM12	ON CENTER ,0.25 M ABOVE 04 LEVEL DECK	25.676	2.122	-14.049
BM13	03 LEVEL TOP OF SCIENTIFIC CONTROL ROOM OUTBOARD	3.373	9.192	-11.153
BM14	03 LEVEL TOP OF SCIENTIFIC CONTROL ROOM INBOARD	3.371	5.421	-11.159
BM15	ON CENTER TOP CB TRUNK ON WALL 0.75M ABOVE 04 LEVEL	22.604	2.122	-14.550
BM16	FWD TRANSDUCER ROOM FWD BH 0.7M ABOVE TANK TOP	27.466	1.308	4.299
BM17	FWD TRANSDUCER ROOM AFT BH 0.7M ABOVE TANK TOP	21.395	1.308	4.299
BM18	AFT TRANSDUCER ROOM, PORT	3.995	0.925	5.041
BM19	AFT TRANSDUCER ROOM, STBD	3.995	3.328	5.417
BM20	UPPER LABORATORY ON AFT BH	18.935	-1.328	-12.805
BM21	NO INSTALLATION	-	-	-
BM22	ELECTRONICS/COMPUTER LAB	30.384	-0.876	-4.572
BM23	ELECTRONICS/COMPUTER LAB	22.620	-0.877	-4.577
BM24	SCIENCE HOLD, PORT, .9 M ABOVE 1ST PLATFORM	1.290	-4.775	-0.706
BM25	ON CENTER, SCIENCE HOLD, 1.7 M ABOVE 1ST PLATFORM	-0.537	2.121	-1.484
BM26	SCIENCE HOLD,STBD , .9 M ABOVE 1ST PLATFORM	1.290	9.032	-0.705

TABLE 2 FEATURES WITH RESPECT TO GRANITE BLOCK, METERS			
FEATURE	**X**	**Y**	**Z**
12Khz AIRMAR	23.146	3.903	6.042
150Khz ADCP	26.130	3.994	6.043
19" SPARE CENTER	23.152	1.503	6.043
19" SPARE PORT	23.156	0.321	6.041
19" SPARE STBD	23.149	2.722	6.043
38 KhZ ADCP	24.880	0.306	6.046
75 Khz ADCP	25.920	0.102	6.044
LSE 297 50 Khz	26.131	2.950	6.043
AFT 19" SPARE TRANSDUCER	4.061	2.566	6.020
AFT 24" SPARE TRANSDUCER	4.317	1.587	6.019
AFT SEA CHEST	-16.070	1.368	2.899
CB @ HULL AFT	19.193	2.113	6.024
CB @ HULL FWD	22.300	2.115	6.049
FWD SEACHEST	36.912	1.546	5.389
LSE 297 200 KhZ	26.211	0.649	6.044
EM 302 TX	28.601	2.122	6.040
EM 302 RX	23.826	2.078	6.043
STBD ANEMOMETER	15.200	3.761	-25.218
PORT ANEMOMETER	15.228	0.453	-25.230
MAGCOMPASS	29.862	2.122	-16.596
CL TOPAS PS 18	25.078	3.568	6.042
EM 710 RX	24.540	2.015	6.042
EM 710TX	25.360	1.141	6.041
Rapp MRU, Top Dead Center	10.262	2.183	-0.992
Kongsberg MRU (Note 4) (Rev 1)	25.459	2.122	-0.884
MT MRU, Top Dead Center	25.251	2.114	-1.073
Gyrocompass No. 1, Top Dead Ctr	25.744	-0.639	-12.414
Gyrocompass No. 2, Top Dead Ctr	25.754	-0.649	-11.902
A-Frame Center Sheave (Note 5)	-21.0362	2.174	-8.832
LHS Crane Sheave (Note 6)	9.104	8.379	-6.107

Note 4 - See Figure 3

Note 5 - See Figure 4

Note 6 - See Figure 5

Elevation of 20 Ft Draftmark, STBD side = -0.324M (Rev 1)

TABLE 3- CENTERBOARD FEATURES WITH RESPECT TO GRANITE BLOCK MEASURED AT HULL, METERS			
FEATURE	**X**	**Y**	**Z**
EK60-70	20.051	2.118	6.030
12" NPS 150# FLANGE	20.525	2.118	6.033
EK60-120	21.592	1.923	6.039
EK60-200	21.593	2.305	6.038
EK60-18	21.158	2.117	6.036
EK60-38	21.951	2.113	6.040

TABLE 4- ANTENNA LOCATION WITH RESPECT TO GRANITE BLOCK-METERS(1)

Number	System/Function	X	Y	Z
1.1	HF#1	24.098	9.357	-16.654
1.2	HF#1	30.528	5.258	-16.685
1.3	HF#2	24.102	-5.125	-16.673
1.4	HF#2	30.548	-1.017	-16.712
10.1	DGPS#1	14.076	1.421	-29.115
10.2	DGPS#2	14.083	0.917	-29.116
10.3	GCGPS(3)	14.061	2.082	-30.523
10.4	AIS GPS	14.061	0.919	-26.950
11.1	INMARSAT C	13.768	0.214	-25.216
11.2	IRIDIUM	13.548	3.618	-25.700
12.1	TV, AM/FM	21.894	-0.400	-18.091
2.1	VHF	31.315	4.060	-17.607
2.2	VHF#1	21.893	3.526	-17.642
2.3	VHF#2	22.536	-2.778	-17.683
2.4	VHF#2	21.908	0.686	-17.657
2.5	VHF#3	27.449	6.996	-20.891
2.6	VHF#4	27.543	-2.838	-20.908
2.7	VHF#5	3.025	9.324	-12.094
2.8	AIS VHF	31.377	0.300	-17.911
3.1	UHF	31.320	2.100	-17.640
4.1	AIRCRAFT	29.558	-3.547	-17.787
5.1	WX FAX	21.890	-1.607	-17.660
5.2	NAVTEX	21.886	5.772	-17.650
6.1	HIGHSEAS NET	25.241	4.921	-17.193
6.2	FLEET BROADBAND	24.210	-1.526	-19.886
7.1	RADIO DIRECION FINDER	16.314	1.614	-25.634
9.1	GPS(3)	15.314	2.082	-30.546
9.2	GPS(3)	12.821	2.064	-30.521
CLS	ANTENNA	25.356	-3.896	-17.921
S-BAND	RADAR (2)	16.792	2.196	-23.030
X-BAND	RADAR (2)	16.906	2.139	-21.511

(1) Coordinates reported at center of antenna at base unless otherwise noted

(2) See Figure 2 for Location of elevation (Z) coordinate

(3) 03-05-2016 Antennas resurveyed after relocation

TABLE 5 TRANSDUCER PITCH, ROLL, AZIMUTH						
Feature	**Azimuth**	**Rotation**	**Pitch**	**Rotation**	**Roll**	**Rotation**
GRANITE BLOCK	0.07820	STBD	0.00000	-	0.00000	-
EM 302 TX	0.02177	STBD	0.00033	BOW DN	0.13588	STBD UP
EM302 RX	0.16152	PORT	0.18122	BOW DN	0.00460	Stbd Dn
TOPAS PS 18	0.02770	STBD	0.08273	BOW UP	0.04310	STBD UP
EM 710 TX	0.17085	STBD	0.04516	BOW UP	0.03240	STBD DN
EM 710 RX	0.25198	PORT	0.13713	BOW UP	0.02530	STBD UP
75 Khz ADCP	45.16800	STBD	0.15663	BOW UP	0.19704	STBD UP
150 Khz ADCP	45.12627	STBD	0.11071	BOW DN	0.31890	STBD DN
LSE 297 50 Khz	-	-	0.47963	BOW UP	0.01129	STBD UP
LSE 297 200 Khz	-	-	0.25628	BOW UP	0.24442	STBD DN
12 Khz AIRMAR	-	-	0.02038	BOW DN	0.39776	STBD UP
Kongsberg MRU (Rev 1)	1.16847	STBD	0.72870	BOW UP	0.15098	STBD UP
CENTERBOARD(3)	0.14671	STBD	0.22530	BOW UP	0.30963	STBD DN
EK60-70(3)	-	-	0.71471	BOW DN	0.10646	STBD UP
EK60-18(3)	-	-	0.07808	BOW DN	0.24115	STBD UP
EK60-120(3)	-	-	1.03124	BOW DN	0.00689	STBD UP
EK60-200(3)	-	-	0.84780	BOW DN	0.24212	STBD UP
EK60-38(3)	-	-	0.17435	BOW DN	0.42036	STBD UP

(3) Centerboard and Transducers, measured with centerboard flush with hull

FIGURE 1- GRANITE BLOCK

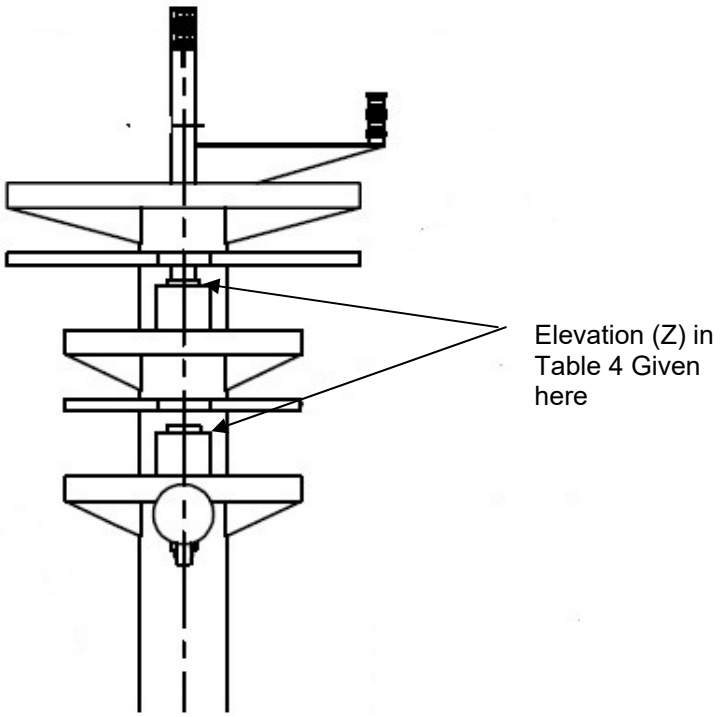


FIGURE 2- X & S BAND RADAR ELEVATION

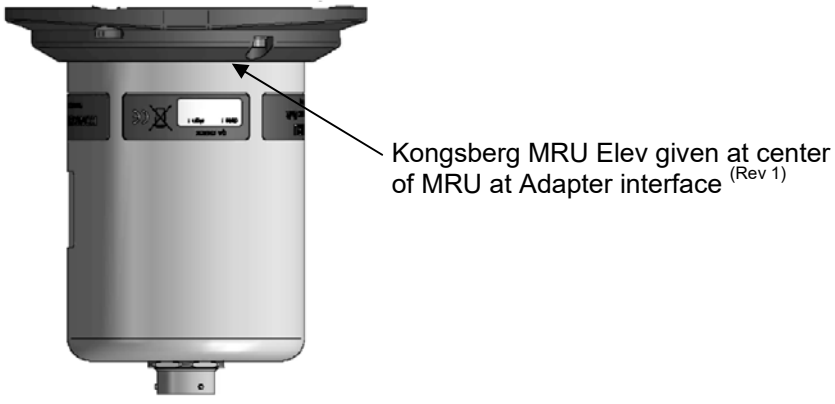


FIGURE 3 – KONGSBERG MRU ELEVATION

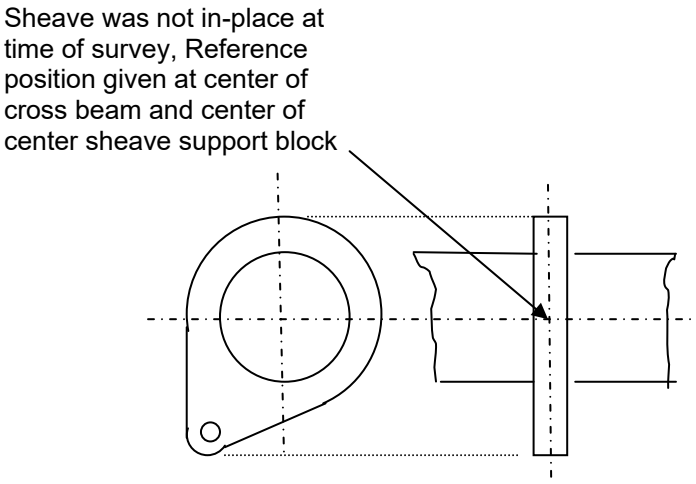


FIGURE 4 – A-FRAME CENTER SHEAVE

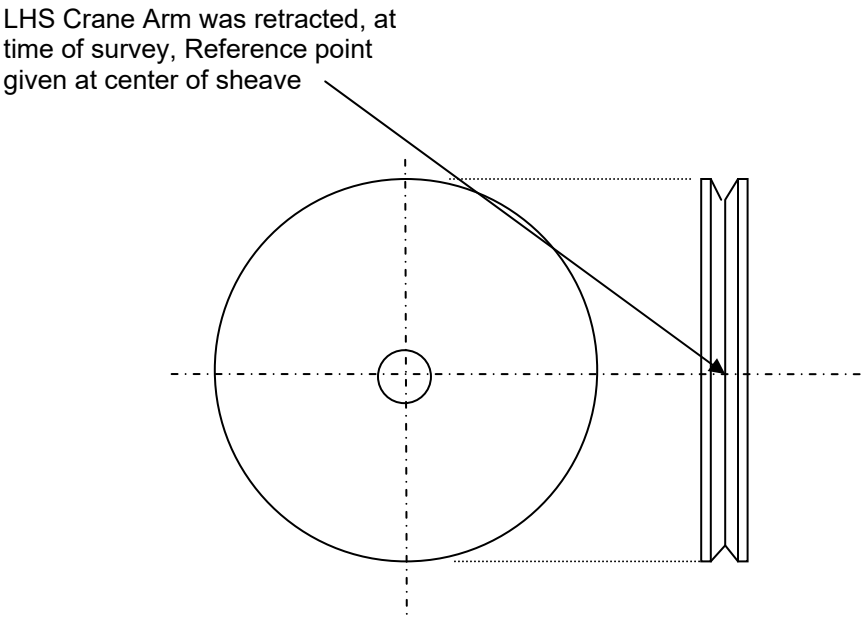
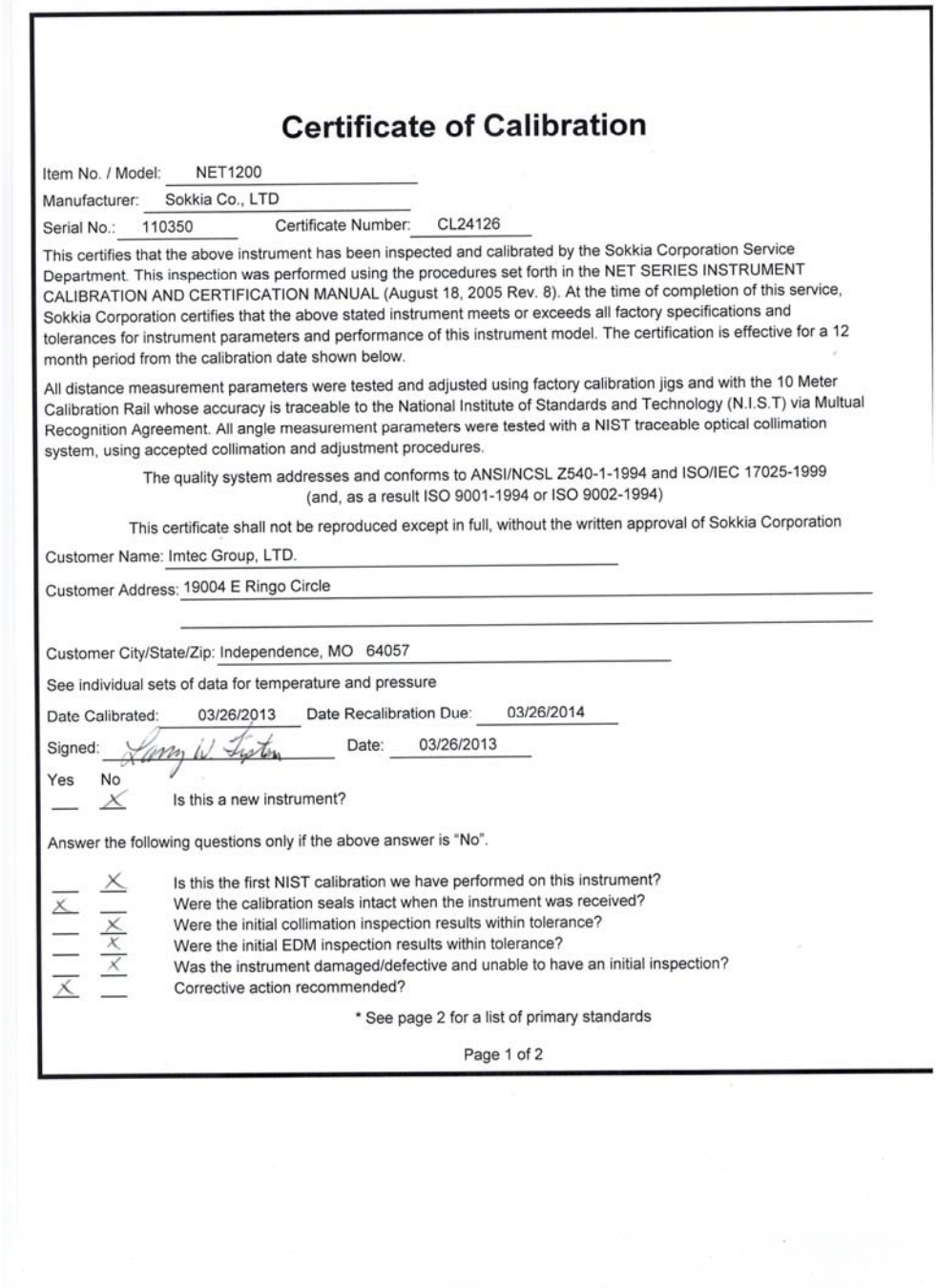


FIGURE 5- LHS CRANE SHEAVE



Certificate of Calibration

Item No. / Model: NET1200

Manufacturer: Sokkia Co., LTD

Serial No.: 110350 Certificate Number: CL24126

This certifies that the above instrument has been inspected and calibrated by the Sokkia Corporation Service Department. This inspection was performed using the procedures set forth in the NET SERIES INSTRUMENT CALIBRATION AND CERTIFICATION MANUAL (August 18, 2005 Rev. 8). At the time of completion of this service, Sokkia Corporation certifies that the above stated instrument meets or exceeds all factory specifications and tolerances for instrument parameters and performance of this instrument model. The certification is effective for a 12 month period from the calibration date shown below.

All distance measurement parameters were tested and adjusted using factory calibration jigs and with the 10 Meter Calibration Rail whose accuracy is traceable to the National Institute of Standards and Technology (N.I.S.T) via Multual Recognition Agreement. All angle measurement parameters were tested with a NIST traceable optical collimation system, using accepted collimation and adjustment procedures.

The quality system addresses and conforms to ANSI/NCSL Z540-1-1994 and ISO/IEC 17025-1999 (and, as a result ISO 9001-1994 or ISO 9002-1994)

This certificate shall not be reproduced except in full, without the written approval of Sokkia Corporation

Customer Name: Imtec Group, LTD.

Customer Address: 19004 E Ringo Circle

Customer City/State/Zip: Independence, MO 64057

See individual sets of data for temperature and pressure

Date Calibrated: 03/26/2013 Date Recalibration Due: 03/26/2014

Signed: Larry W. Tipton Date: 03/26/2013

Yes	No	
___	X	Is this a new instrument?

Answer the following questions only if the above answer is “No”.

___	X	Is this the first NIST calibration we have performed on this instrument?
X	___	Were the calibration seals intact when the instrument was received?
___	X	Were the initial collimation inspection results within tolerance?
___	X	Were the initial EDM inspection results within tolerance?
___	X	Was the instrument damaged/defective and unable to have an initial inspection?
X	___	Corrective action recommended?

* See page 2 for a list of primary standards

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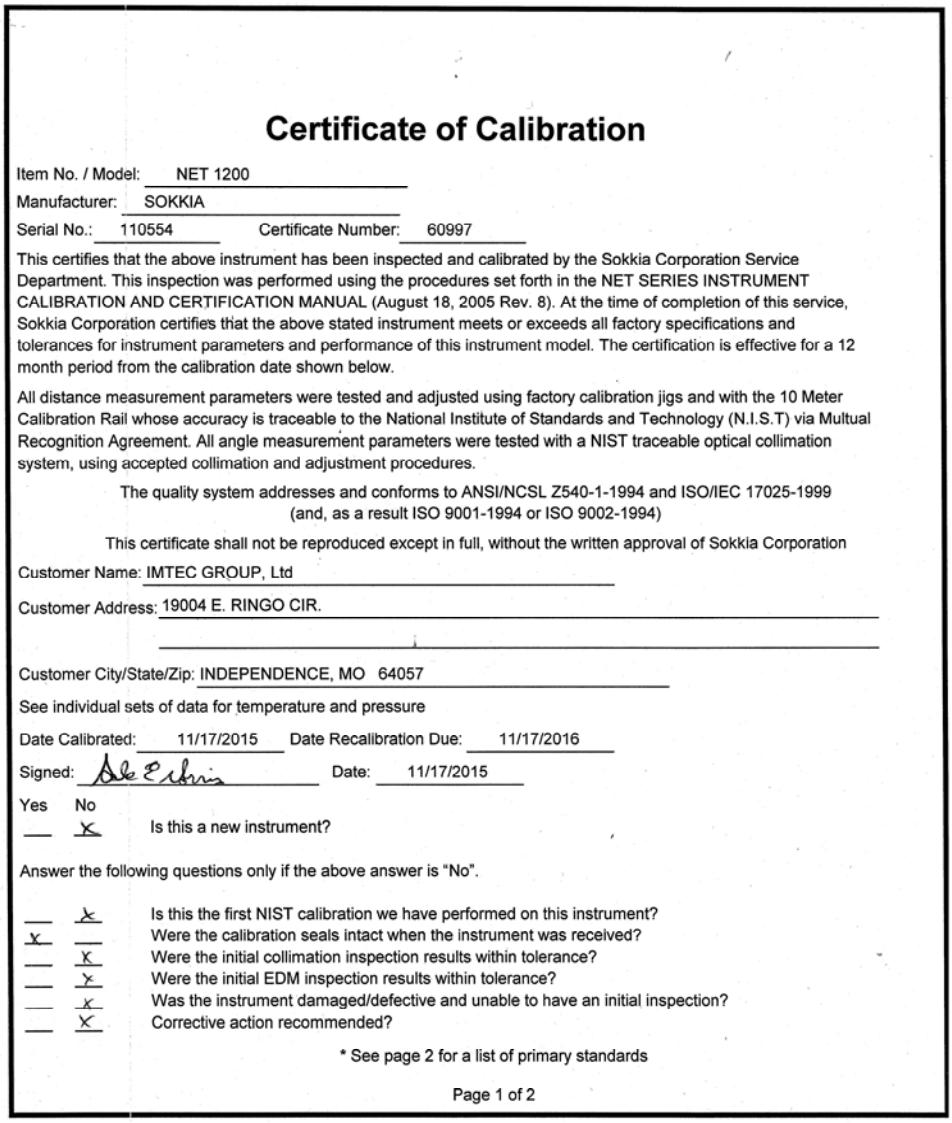
FIGURE 6- SAMPLE INSTRUMENT CALIBRATION CERTIFICATE



Certificate of Calibration

Item No. / Model: NET 1200

Manufacturer: SOKKIA

Serial No.: 110554 Certificate Number: 60997

This certifies that the above instrument has been inspected and calibrated by the Sokkia Corporation Service Department. This inspection was performed using the procedures set forth in the NET SERIES INSTRUMENT CALIBRATION AND CERTIFICATION MANUAL (August 18, 2005 Rev. 8). At the time of completion of this service, Sokkia Corporation certifies that the above stated instrument meets or exceeds all factory specifications and tolerances for instrument parameters and performance of this instrument model. The certification is effective for a 12 month period from the calibration date shown below.

All distance measurement parameters were tested and adjusted using factory calibration jigs and with the 10 Meter Calibration Rail whose accuracy is traceable to the National Institute of Standards and Technology (N.I.S.T) via Multual Recognition Agreement. All angle measurement parameters were tested with a NIST traceable optical collimation system, using accepted collimation and adjustment procedures.

The quality system addresses and conforms to ANSI/NCSL Z540-1-1994 and ISO/IEC 17025-1999 (and, as a result ISO 9001-1994 or ISO 9002-1994)

This certificate shall not be reproduced except in full, without the written approval of Sokkia Corporation

Customer Name: IMTEC GROUP, Ltd

Customer Address: 19004 E. RINGO CIR.

Customer City/State/Zip: INDEPENDENCE, MO 64057

See individual sets of data for temperature and pressure

Date Calibrated: 11/17/2015 Date Recalibration Due: 11/17/2016

Signed: Date: 11/17/2015

Yes	No	
___	X	Is this a new instrument?

Answer the following questions only if the above answer is “No”.

___	X	Is this the first NIST calibration we have performed on this instrument?
X	___	Were the calibration seals intact when the instrument was received?
___	X	Were the initial collimation inspection results within tolerance?
___	X	Were the initial EDM inspection results within tolerance?
___	X	Was the instrument damaged/defective and unable to have an initial inspection?
___	X	Corrective action recommended?

* See page 2 for a list of primary standards

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FIGURE 7- INSTRUMENT CALIBRATION CERTIFICATE 11-17-2015