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**NATO ARMY ARMAMENTS GROUP
LAND GROUP 4 ON INDIRECT FIRE SYSTEMS (LG/4)**

**SUB-GROUP 2 ON ACCURACY, BALLISTICS
AND EXPLOSIVES (SG/2)**

MEASUREMENT OF PROJECTILE VELOCITIES

**AEP-34
EDITION 3**

June 2006

AEP-34
(Edition 3)

NORTH ATLANTIC TREATY ORGANIZATION

NATO STANDARDISATION AGENCY

NATO LETTER OF PROMULGATION

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1. AEP-34 (Edition 3) – MEASUREMENTS OF PROJECTILE VELOCITIES is a NATO UNCLASSIFIED publication. The agreement to use this publication is recorded in STANAG 4114.

2. AEP-34 (Edition 3) is effective upon receipt. It supersedes AEP-34 (Edition 2) which should be destroyed in accordance with the local procedure for the destruction of documents.

3. AEP-34 (Edition 3) contains only factual information. Changes to the AEP are not subject to the ratification procedures and will be promulgated on receipt from the nations concerned after endorsement by the AC/225(LG/4-SG/2) in plenary session.

J. MAJ
Brigadier General, POL(A)
Director, NSA

RECORD OF CHANGES

Change Date	Date Entered	Effective Date	By Whom Entered

TABLE OF CONTENTS

Part I

LIST OF VELOCITY MEASUREMENT SYSTEMS APPROVED BY NATO

AEP- 34

LIST OF VELOCITY MEASUREMENT SYSTEMS APPROVED BY NATO[1)] TO BE USED IN THE PRODUCTION AND TESTING OF NATO STANDARDIZED GUNS AND AMMUNITION

NATIONS: AUSTRIA, BELGIUM, BULGARIA, CANADA, ESTONIA, ICELAND, LATVIA, LITHUANIA, LUXEMBOURG, POLAND, ROMANIA, SLOVAKIA, SLOVENIA

MEASUREMENT SYSTEM (COUNTRY OF ORIGIN)	**TYPE**	**APPLICATION**			**SYSTEM SPECIFI-CATION SHEET No.**
		Calibre - Small (S) - Medium (M) - Large (L)	**Use** - Field (F) - Proving Ground (PG)	**Elevation** - Horizontal (H) - Angle (A)	
NO APPROVED SYSTEM IN USE. **INTENTIONALLY BLANK.**					

1) alternatively by ISO 9001

LIST OF VELOCITY MEASUREMENT SYSTEMS APPROVED BY NATO[1)] TO BE USED IN THE PRODUCTION AND TESTING OF NATO STANDARDIZED GUNS AND AMMUNITION

NATION: CZECH REPUBLIC (CZE)					
MEASUREMENT SYSTEM (COUNTRY OF ORIGIN)	**TYPE**	**APPLICATION**			**SYSTEM SPECIFI-CATION SHEET No.**
		Calibre - Small (S) - Medium (M) - Large (L)	**Use** - Field (F) - Proving Ground (PG)	**Elevation** - Horizontal (H) - Angle (A)	
DOPPLER RADAR TERMA (DNK)	DR5000 S-Band	S + M + L	PG	H + A	A-8
DOPPLER RADAR WEIBEL (DNK)	MVRS W-700	S + M + L	F + PG	H + A	A-17

1) alternatively by ISO 9001

LIST OF VELOCITY MEASUREMENT SYSTEMS APPROVED BY NATO[1)] TO BE USED IN THE PRODUCTION AND TESTING OF NATO STANDARDIZED GUNS AND AMMUNITION

NATION: DENMARK (DNK)					
MEASUREMENT SYSTEM (COUNTRY OF ORIGIN)	**TYPE**	**APPLICATION**			**SYSTEM SPECIFI-CATION SHEET No.**
		Calibre - Small (S) - Medium (M) - Large (L)	**Use** - Field (F) - Proving Ground (PG)	**Elevation** - Horizontal (H) - Angle (A)	
DOPPLER RADAR TERMA (DNK) (LEAR SIEGLER, USA)	DR810	S + M + L	F + PG	H + A	A-1
DOPPLER RADAR TERMA (DNK)	BS900	M + L	F + PG	H + A	A-2
DOPPLER RADAR TERMA (DNK)	BS850	S + M + L	PG	H + A	A-3
SKY SCREEN TERMA (DNK)	E0300	S + M + L	PG	H	A-4
SKY SCREEN TERMA (DNK)	E0350	S + M + L	PG	H	A-5
LIGHT SCREEN TERMA (DNK)	EV120	S + M + L	PG	H	A-6
LIGHT SCREEN TERMA (DNK)	EV100	S + M	PG	H	A-7
DOPPLER RADAR TERMA (DNK)	DR5000 (S-Band + X-Band)	S + M + L	PG	H + A	A-8
DOPPLER RADAR WEIBEL (DNK)	SL-520P SL-525P SL-15028P SL-30031P	S + M + L	PG	H + A	A-14

1) alternatively by ISO 9001

LIST OF VELOCITY MEASUREMENT SYSTEMS APPROVED BY NATO[1)] TO BE USED IN THE PRODUCTION AND TESTING OF NATO STANDARDIZED GUNS AND AMMUNITION

NATION: FINLAND (FIN)					
MEASUREMENT SYSTEM (COUNTRY OF ORIGIN)	**TYPE**	**APPLICATION**			**SYSTEM SPECIFI-CATION SHEET No.**
		Calibre - Small (S) - Medium (M) - Large (L)	**Use** - Field (F) - Proving Ground (PG)	**Elevation** - Horizontal (H) - Angle (A)	
SKY-SCREEN WEIBEL (DNK)	GP80	S + M + L	PG	H	A-11
DOPPLER RADAR Weibel (DNK)	MVRS W-700 W-680 W-1000	S+ M + L	F + PG	H + A	A-17

1) alternatively by ISO 9001

LIST OF VELOCITY MEASUREMENT SYSTEMS APPROVED BY NATO[1)] TO BE USED IN THE PRODUCTION AND TESTING OF NATO STANDARDIZED GUNS AND AMMUNITION

NATION: FRANCE (FRA)					
MEASUREMENT SYSTEM (COUNTRY OF ORIGIN)	**TYPE**	**APPLICATION**			**SYSTEM SPECIFI-CATION SHEET No.**
		Calibre - Small (S) - Medium (M) - Large (L)	**Use** - Field (F) - Proving Ground (PG)	**Elevation** - Horizontal (H) - Angle (A)	
MAGNETIC COIL ETBS (FRA)	Base-Sole-noides	S + M + L	PG	A	A-10
SKY SCREEN WEIBEL (DNK)	SW 90	S + M + L	PG	H	A-11
DOPPLER RADAR WEIBEL (DNK)	MVRS W-700	S + M + L	F + PG	H + A	A-17
LIGHT SCREEN ETBS (FRA)	Base ETBS-Boir	S + M + L	PG	A	A-18
LIGHT SCREEN ETBS (FRA)	Base ETBS-Bomet	S + M + L	PG	H	A-19
DOPPLER RADAR IN-SNEC (FRA)	RDB-4	M + L	F + PG	H + A	A-20

1) alternatively by ISO 9001

LIST OF VELOCITY MEASUREMENT SYSTEMS APPROVED BY NATO[1)] TO BE USED IN THE PRODUCTION AND TESTING OF NATO STANDARDIZED GUNS AND AMMUNITION

NATION: GERMANY (DEU)					
MEASUREMENT SYSTEM (COUNTRY OF ORIGIN)	**TYPE**	**APPLICATION**			**SYSTEM SPECIFI-CATION SHEET No.**
		Calibre - Small (S) - Medium (M) - Large (L)	**Use** - Field (F) - Proving Ground (PG)	**Elevation** - Horizontal (H) - Angle (A)	
DOPPLER RADAR LEAR SIEGLER (USA)	DR810	M + L	F + PG	H + A	A-1
DOPPLER RADAR TERMA (DNK)	BS850	S + M + L	PG	H + A	A-3
DOPPLER RADAR TERMA (DNK)	DR5000	S + M + L	PG	H + A	A-8
OPTICAL SKY SCREEN WEIBEL (DNK) MILLIGAN (GBR)	GP80 + CINTEL H	S + M + L	PG	H	A-11
INDUCTIVE COIL WTD 91 (DEU)	Mono-Spire	S + M + L	PG	H + A	A-12
DOPPLER RADAR WEIBEL (DNK)	SL-520P SL-525P SL-15028P SL-30031P	S + M + L	PG	H + A	A-14
DOPPLER RADAR WEIBEL (DNK)	MVRS W-700 W-1000	S + M + L	PG	H + A	A-17

1) alternatively by ISO 9001

LIST OF VELOCITY MEASUREMENT SYSTEMS APPROVED BY NATO[1)] TO BE USED IN THE PRODUCTION AND TESTING OF NATO STANDARDIZED GUNS AND AMMUNITION

NATION: GREECE (GRC)					
MEASUREMENT SYSTEM (COUNTRYOF ORIGIN)	**TYPE**	**APPLICATION**			**SYSTEM SPECIFI-CATION SHEET No.**
		Calibre - Small (S) - Medium (M) - Large (L)	**Use** - Field (F) - Proving Ground (PG)	**Elevation** - Horizontal (H) - Angle (A)	
DOPPLER RADAR LEAR SIEGLER (USA)	DR 810 MK II	M + L	F + PG	H + A	A-1
SKY SCREEN TERMA (DNK)	EO 350	S + M + L	PG	H + A	A-5
DOPPLER RADAR TERMA (DNK)	DR-582	S + M + L	PG	H + A	A-16

1) alternatively by ISO 9001

LIST OF VELOCITY MEASUREMENT SYSTEMS APPROVED BY NATO[1)] TO BE USED IN THE PRODUCTION AND TESTING OF NATO STANDARDIZED GUNS AND AMMUNITION

NATION: ITALY (ITA)					
MEASUREMENT SYSTEM (COUNTRY OF ORIGIN)	**TYPE**	**APPLICATION**			**SYSTEM SPECIFI-CATION SHEET No.**
		Calibre - Small (S) - Medium (M) - Large (L)	**Use** - Field (F) - Proving Ground (PG)	**Elevation** - Horizontal (H) - Angle (A)	
DOPPLER RADAR TERMA (DNK)	BS850	S + M + L	PG	H + A	A-3
OPTICAL SKY-SCREEN OPOS ELECTRONICS (DNK)	EO350 CC2000	M + L	PG	H	A-5
DOPPLER RADAR TERMA (DNK)	DR5000 (S-Band + X-Band)	S + M + L	PG	H + A	A-8
OPTICAL SKY-SCREEN WEIBEL (DNK)	GP80 + W640	S + M + L	PG	H	A-11
OPTICAL SKY-SCREEN SABRE (GBR)	PCC WFR 421/ MCC222	S + M + L	PG	H + A	A-13
DOPPLER RADAR WEIBEL (DNK)	MVRS W-700	S + M + L	PG	H + A	A-17

1) alternatively by ISO 9001

LIST OF VELOCITY MEASUREMENT SYSTEMS APPROVED BY NATO[1)] TO BE USED IN THE PRODUCTION AND TESTING OF NATO STANDARDIZED GUNS AND AMMUNITION

NATION: THE NETHERLANDS (NLD)					
MEASUREMENT SYSTEM (COUNTRY OF ORIGIN)	**TYPE**	**APPLICATION**			**SYSTEM SPECIFI-CATION SHEET No.**
		Calibre - Small (S) - Medium (M) - Large (L)	**Use** - Field (F) - Proving Ground (PG)	**Elevation** - Horizontal (H) - Angle (A)	
DOPPLER RADAR WEIBEL (DNK)	SL-520P SL-525P SL-15028P SL-30031P	S + M + L	PG	H + A	A-14
DOPPLER RADAR WEIBEL (DNK)	MVRS W-700	S + M + L	F + PG	H + A	A-17

1) alternatively by ISO 9001

LIST OF VELOCITY MEASUREMENT SYSTEMS APPROVED BY NATO[1)] TO BE USED IN THE PRODUCTION AND TESTING OF NATO STANDARDIZED GUNS AND AMMUNITION

NATION: NORWAY (NOR)					
MEASUREMENT SYSTEM (COUNTRY OF ORIGIN)	**TYPE**	**APPLICATION**			**SYSTEM SPECIFI-CATION SHEET No.**
		Calibre - Small (S) - Medium (M) - Large (L)	**Use** - Field (F) - Proving Ground (PG)	**Elevation** - Horizontal (H) - Angle (A)	
DOPPLER RADAR OPUS (DNK)	BS850	S + M + L	PG	H + A	A-3
DOPPLER RADAR TERMA (DNK)	DR5000	S + M + L	PG	H + A	A-8
SKY SCREEN WEIBEL (DNK)	GP80	S + M + L	PG	H	A-11
DOPPLER RADAR AWA DI (AUS)	MVI MK3 AN/UPQ - 501	M + L	F	H + A	A-15
DOPPLER RADAR WEIBEL (DNK)	MVRS W-700 W-1000 W-700SCD	S + M + L	PG	H + A	A-17
INDUCTIVE COIL RAUFOSS (NOR) CRONOMETER WEIBEL	Mono-spere W640	S + M + L	PG	H	2)

1) alternatively by ISO 9001
2) Specification Sheet not available

LIST OF VELOCITY MEASUREMENT SYSTEMS APPROVED BY NATO[1)] TO BE USED IN THE PRODUCTION AND TESTING OF NATO STANDARDIZED GUNS AND AMMUNITION

NATION: SPAIN (ESP)					
MEASUREMENT SYSTEM (COUNTRY OF ORIGIN)	**TYPE**	**APPLICATION**			**SYSTEM SPECIFI-CATION SHEET No.**
		Calibre - Small (S) - Medium (M) - Large (L)	**Use** - Field (F) - Proving Ground (PG)	**Elevation** - Horizontal (H) - Angle (A)	
DOPPLER RADAR TERMA (DNK)	DR 810	M + L	PG	H + A	A-1
DOPPLER RADAR TERMA (DNK)	DR 5000 S-Band and X-Band	S + M + L	PG	H + A	A-8
SKY SCREEN WEIBEL (DNK)	SW90	S + M + L	PG	H + A	A-11
DOPPLER RADAR TERMA (DNK)	DR 582	S + M + L	PG	H + A	A-16
DOPPLER RADAR WEIBEL (DNK)	MVRS W-700 W-680	S + M + L	F + PG	H + A	A-17

1) alternatively by ISO 9001

LIST OF VELOCITY MEASUREMENT SYSTEMS APPROVED BY NATO[1)] TO BE USED IN THE PRODUCTION AND TESTING OF NATO STANDARDIZED GUNS AND AMMUNITION

NATION: SWEDEN (SWE)					
MEASUREMENT SYSTEM (COUNTRY OF ORIGIN)	**TYPE**	**APPLICATION**			**SYSTEM SPECIFI-CATION SHEET No.**
		Calibre - Small (S) - Medium (M) - Large (L)	**Use** - Field (F) - Proving Ground (PG)	**Elevation** - Horizontal (H) - Angle (A)	
DOPPLER RADAR WEIBEL (DNK)	SL-520P SL-525P SL-15028P SL-30031P	S + M + L	PG	H + A	A-14

1) alternatively by ISO 9001

LIST OF VELOCITY MEASUREMENT SYSTEMS APPROVED BY NATO[1)] TO BE USED IN THE PRODUCTION AND TESTING OF NATO STANDARDIZED GUNS AND AMMUNITION

NATION: TURKEY (TUR)					
MEASUREMENT SYSTEM (COUNTRY OF ORIGIN)	**TYPE**	**APPLICATION**			**SYSTEM SPECIFI-CATION SHEET No.**
		Calibre - Small (S) - Medium (M) - Large (L)	**Use** - Field (F) - Proving Ground (PG)	**Elevation** - Horizontal (H) - Angle (A)	
DOPPLER RADAR LEAR SIEGLER (USA)	DR810	M + L	F + PG	H + A	A-1
SKY SCREEN TERMA (DNK)	EO350	S + M + L	PG	H	A-5
INDUCTIVE COIL INDUSTRY (DEU)	Mono-spire	S + M + L	PG	H + A	A-12
DOPPLER RADAR WEIBEL (DNK)	MVRS W-700	S + M + L	F + PG	H + A	A-17

1) alternatively by ISO 9001

LIST OF VELOCITY MEASUREMENT SYSTEMS APPROVED BY NATO[1] TO BE USED IN THE PRODUCTION AND TESTING OF NATO STANDARDIZED GUNS AND AMMUNITION

NATION: UNITED KINGDOM (GBR)					
MEASUREMENT SYSTEM (COUNTRY OF ORIGIN)	**TYPE**	**APPLICATION**			**SYSTEM SPECIFICATION SHEET No.**
		Calibre - Small (S) - Medium (M) - Large (L)	**Use** - Field (F) - Proving Ground (PG)	**Elevation** - Horizontal (H) - Angle (A)	
DOPPLER RADAR TERMA (DNK)	DR810 MKI and MK II	M + L	PG	H + A	A-1
DOPPLER RADAR TERMA (DNK)	DR5000 velocity analyzer 2)	S + M + L	PG	H + A	A-8
DOPPLER RADAR MARCONI MARCAL (GBR)	MVMD	M + L	F	H + A	A-9
MILLIGAN PCC (GBR) AND MSI TYPE 758 AUTOMATIC (GBR)	PCC	S + M + L	PG	H + A	A-13
DOPPLER RADAR WEIBEL (DNK)	SL-520P SL-525P SL-15028P SL-30031P	S + M + L	PG	H + A	A-14
DOPPLER RADAR WEIBEL (DNK)	MVRS W-680 W-700 W-1000	S + M + L	PG	H	A-17

1) Alternatively by ISO 9001

2) With DR819 Antenna, ED5100 Antenna, ED6000 Antenna, ED5200 Antenna, 1.6 degree X-Band Antenna, 3.2 degree X-Band Antenna or ED6500 Antenna

LIST OF VELOCITY MEASUREMENT SYSTEMS APPROVED BY NATO[1)] TO BE USED IN THE PRODUCTION AND TESTING OF NATO STANDARDIZED GUNS AND AMMUNITION

NATION: UNITED STATES (USA)					
MEASUREMENT SYSTEM (COUNTRY OF ORIGIN)	**TYPE**	**APPLICATION**			**SYSTEM SPECIFI-CATION SHEET No.**
		Calibre - Small (S) - Medium (M) - Large (L)	**Use** - Field (F) - Proving Ground (PG)	**Elevation** - Horizontal (H) - Angle (A)	
DOPPLER RADAR LEAR SIEGLER (USA)	DR810 (M90)	M + L	F	H + A	A-1
DOPPLER RADAR TERMA (DNK)	BS850	S + M + L	PG	H + A	A-3
DOPPLER RADAR TERMA (DNK)	DR5000 (X-Band)	S + M + L	PG	H + A	A-8
SKY SCREEN WEIBEL (DNK)	GP80 and SW 90	S + M + L	PG	H	A-11
DOPPLER RADAR WEIBEL (DNK)	SL-520P SL-525P SL-15028P SL-30031P	S + M + L	PG	H + A	A-14
DOPPLER RADAR WEIBEL (DNK)	MVRS W-700 W-680 W-1000	S + M + L	F + PG	H + A	A-17

1) alternatively by ISO 9001

PART II

SYSTEM SPECIFICATION SHEETS

OF APPROVED VELOCITY MEASUREMENT SYSTEMS

AEP- 34

GENERAL OPERATIONAL REQUIREMENTS

The velocity measurement systems listed at Part I are given NATO approval under the conditions mentioned in the specifications attached.

1. Such approval is provisionally restricted to projectiles without fins or tracers. Projectiles with discarding sabots, tracers, base-burn and rocket motors are not included in projectile types measured by the systems in Part I unless noted on the specification sheets. However, when analysing Doppler radar signals it is possible to include these projectiles using techniques such as Fast Fourier Transforms (FFT's).

2. This list is not restrictive and can be extended as specified in Part IV.

3. To be considered valid, NATO measurements[1)] shall be at least duplicated (instrument with a minimum of two channels or two instruments with a single channel). It is moreover recommended that, as far as possible, different types of instruments be used.

4. All nations are responsible for proper calibration of the velocity measurement systems used for NATO testing.[1)]

Abbreviations, used in the tables:

VM:	Velocity Meter
MV:	Muzzle Velocity
PM:	Per Minute
PP:	Per Projectile
R.o.F.:	Rate-of-Fire
FFT	Fast Fourier Transformation
r.p.m	Rounds per Minute

[1)] Alternativ ISO 9001 procedures

PART II

SYSTEM SPECIFICATION SHEETS OF APPROVED VELOCITY MEASUREMENT SYSTEMS

Sheet No.	System Name	Test Report Reference	Approval Date		User Nation
			LG/4-SG/2	ISO 9001	
A-1 II-5	DR810 Muzzle Velocity Analyser	Proof and Experimental Test Establishment Report on Trial PETE 10081-797 Nicolet, Quebec, CAN 12 July 1977	Sep 1977		DEU DNK ESP GBR GRC TUR USA
A-2 II-8	BS 900 Muzzle Velocity Meter	Danish Artillery School Report No.: TJ/FO/ 601.1-395/1631 Varde / DNK 28 Sept 1981	Nov 1981		DNK
A-3 II-10	BS 850 Velocity Analyser	Danish Artillery School Report on Romo Beach Tests, DNK 29 Sept 1988	Nov 1988		CAN DEU DNK ITA NOR USA
A-4 II-13	EO 300 Wide-Angle Sky Screen	Danish Artillery School Report on Romo Beach Tests, DNK 30 Sept 1988	Nov 1988		DNK
A-5 II-15	EO 350 Sky Screen	Danish Artillery School Report on Romo Beach Tests, DNK 30 Sept 1988	Nov 1988		DNK GRC ITA TUR
A-6 II-17	EV 120 IR Reflex Screen	Danish Artillery School Report on Romo Beach Tests, DNK 2 Oct 1988	Dec 1988		DNK
A-7 II-19	EV 100 Photocell Transducer System	Danish Artillery School Report on Romo Beach Tests, DNK 2 Oct 1988	Dec 1988		DNK
A-8 II-21	DR 5000 Velocity Analyser	*S-Band Doppler Radar* *X-Band Doppler Radar* Danish Artillery School Two Reports on Borris Range Tests, DNK Varde, 1 Feb 1994	Apr 1994		CZE DEU DNK ESP GBR ITA NOR USA
A-9 II-24	Marcal MVMD	n.a. [1)]	-		GBR
A-10 II-26	Single/Multiple Turn Solenoid Frames	n.a.	-		FRA

1) Not available

Sheet No.	System Name	Test Report Reference	Approval Date		User Nation
			LG/4-SG/2	ISO 9001	
A-11 II-29	Sky Screens CINTEL H or GP 80, SW 90	n.a.	-	-	DEU ESP FIN FRA ITA NOR USA
A-12 II-31	Spulenbasis Inductive Coils	n.a.	-	-	DEU TUR
A-13 II-33	PCC Photocell Counter Chronometer	n.a.	-	-	GBR ITA
A-14 II-36	1. SL-520P 2. SL-525 P 3. SL-15028P 4. SL-30031P Doppler Radar System	1., 2. Danish Army Artillery School, Technical Division, DNK 26th May 2005 3. Danish Army Artillery School, Technical Division, DNK 26th May 2005 4. Danish Army Artillery School, Technical Division, DNK 26th May 2005	Sep 2005 Sep 2005 Sep 2005	-	DEU DNK GBR NLD SWE USA 2)
A-15 II-39	MVI MK 3 Muzzle Velocity Indicator	n.a.	-		NOR
A-16 II-42	DR 582 Velocity/Trajectory Analyser	Danish Artillery School Report at Borris Range Tests, DNK 10 May 1995	Jul 1995		ESP GRC
A-17 II-45	MVRS W-700 W-680, W-1000 1)2)	Danish Artillery School Report at Borris and Oskbol Range Tests, DNK 17 Oct 1996	Dec 1996		CZE DEU ESP FIN FRA GBR ITA NLD NOR TUR USA 2)
A-18 II-48	BOIR LG 500/LG 1000 Infrared Optical Barriers	DGA, Bourges, FRA Report No.: 347 18 Sept 1997	Nov 1997		FRA
A-19 II-51	BOMET Infrared Optical Barriers	DGA, Bourges, FRA Report No.: 343 29 Aug 1997	Oct 1997		FRA
A-20 II-54	RDB-4 Artillery Velocity Meter	DGA, Bourges, FRA Report No.: 348 18 Sept 1997	Nov 1997		FRA

1) W680 and W1000 are not in the report (W-680 is an old version of W-700; W-1000 is comparable with W-700 having another analyser).
2) Nations use at least one of the systems.

SYSTEM SPECIFICATION SHEET	No.: A-1
	-
SYSTEM used by	**DEU, DNK, ESP, GBR, GRC, TUR, USA**

Function	Specifications	
DETECTOR	System	Electro-magnetic
	Type of detector	Doppler antenna
	Name	DR810 MK II Muzzle Velocity Meter
	Manufacturer (Country of Origin)	Lear Siegler Inc., California USA DNK: Terma Elektronik AS DNK
	Transmitter frequency	10525 GHz ± 0.3 MHz CAN: 10525 GHz ± 10 MHz
	Transmitter power	>200 mW (continues wave)
	Antenna gain	21 dB
	Warming up	not required
	Base length (and tolerance)	-
OPERATION	General description	The frequency shift of the received signal is proportional to the radial velocity of the projectile. To obtain this frequency shift, the emitted and received signals are mixed.
AMPLIFIERS	General description	-
CHRONOMETERS	Description	-
COUNTERS	Name	-
	Manufacturer	-
	Time base resolution	-
	Measuring base resolution	-
	Read out	-
	Number of counters	-
	Independence of counters	-
	Precision	-
	Crystal stability	-
	Crystal in temperature control oven	-

Table continues

SYSTEM SPECIFICATION SHEET	No.: A-1
	continued

Function	Specifications	
OUTPUT	General description	-
	Display	1. 5 digit numeric, giving muzzle velocity in m/s 2. ΔV, the velocity drop from the muzzle to the average of the 7 measurements points 3. v_0, the average of the valid recorded shots 4. N, the number of rounds used in the average (maximum eight)
METHOD OF CALCULATION OF THE VELOCITY	General description of the method used for the calculation of the velocity of a projectile at a specific point (e.g. initial velocity).	The muzzle velocity is automatically calculated by measuring the velocity of the projectile at 7 points along the trajectory and then extrapolated back to the muzzle using a least squares fit. Different models will use different numbers of points, e.g. 52 points with bases of 1.8 m along the trajectory from 8 m to 212 m in front of the gun-muzzle.
SIMULATION	General description	Simulator test equipment is provided.
ESTIMATED ACCURACY	Velocity	Better than 0.1 % of velocity
ERROR INDICATION	General description	The system automatically indicates when a measurement may be incorrect.
APPLICATIONS FIELD OF USE	Calibre range	40 mm and up
	Velocity range	50 m/s - 1750 m/s

Table continues

SYSTEM SPECIFICATION SHEET	No.: A-1
	continued

Function	Specifications		
APPLICATIONS FIELD OF USE CONTINUED	Elevation range		3° - 90°
	Adjustable trajectories of measurements		First measuring point can be set at 30, 60, 120 or 180 metres from the muzzle.
	Temperature range	-	-40 °C to +70 °C DEU: -40 °C to +55 °C
		-	-
	Rate-of-Fire		Rapid fire provided only one round in the beam at a time with a maximum of 20 rounds/minute.
	Projectile types		-
SPECIALS	-		-
RESTRICTIONS	The equipment can not be used with		Moving objects in the main lobe of the antenna. Obstacles of ¼ wavelength at the bottom of the shell. Shells with discarding sabots in the beam beyond the first measuring point.
INCOMPATIBLE	with		-
Table ends			

SYSTEM SPECIFICATION SHEET	No.: A-2
	-
SYSTEM used by	**DNK**

Function	Specifications	
DETECTOR	System	Electro-magnetic
	Type of detector	Doppler radar
	Name	BS 900 Muzzle Velocity Meter
	Manufacturer (Country of Origin)	OPOS ELECTRONICS A/S, DNK Terma Elektronik AS, DNK
	Transmitter frequency	10525 MHz
	Transmitter power	~150 mW (continues wave)
	Antenna gain	-
	Warming up	not required
	Base length (and tolerance)	-
OPERATION	General description	The frequency shift of the received signal is proportional to the radial velocity of the projectile. To obtain this frequency shift, the emitted and received signals are mixed.
AMPLIFIERS	General description	-
CHRONOMETERS	Description	-
COUNTERS	Name	-
	Manufacturer	-
	Time base resolution	-
	Measuring base resolution	-
	Read out	-
	Number of counters	-
	Independency of counters	-
	Precision	-
	Crystal stability	-
	Crystal in temperature control oven	-
OUTPUT	General description	-
	Display	5 digit numeric, giving muzzle velocity v_0 in m/s with 0.1 m/s resolution;

Table continues

SYSTEM SPECIFICATION SHEET	No.: A-2
	continued

Function	Specifications		
OUTPUT CONTINUED	Display		the average of the valid shots recorded and number of rounds used in the average calculation (max ten). For firing range use a printer option –05 gives extrapolated v_0 decrease in velocity in m/s/m as well as actual distance to these measuring points.
SIMULATION	General description		Simulator test equipment is provided.
ESTIMATED ACCURACY	Velocity		Better than 0.1 % of velocity.
ERROR INDICATION	General description		The system automatically indicates when a measurement is unreliable.
APPLICATIONS FIELD OF USE	Calibre range		20 mm and up
	Velocity range		50 m/s - 1765 m/s
	Elevation range		0° to 90°
	Adjustable trajectories of measurements		First measuring point can be set at 15, 30, 60, 90, 120, 150 or 190 metres from the muzzle.
	Temperature range	-	-30 °C to +55 °C
		-	-
	Rate-of-Fire		Rapid fire possible as long as next round is fired after measuring of previous round was completed (max Rate-of-Fire app. 1200 r.p.m.)
	Projectile types		-
SPECIALS	-		-
RESTRICTIONS	The equipment can not be used at		1. Moving objects in the main lobe of the antenna. 2. Obstacles of ¼ wave length at the bottom of the shell. 3. Shells with discarding sabots in the beam beyond the first measuring point.
INCOMPATIBLE	with		-
Table ends			

SYSTEM SPECIFICATION SHEET	No.: A-3
	-
SYSTEM used by	**CAN, DEU, DNK, ITA, NOR, USA**

Function	Specifications	
DETECTOR	System	Electro-magnetic
	Type of detector	Doppler radar
	Name	BS 850 Velocity Analyzer
	Manufacturer (Country of Origin)	OPOS ELECTRONICS A/S DNK, Terma Elektronik AS, DNK
	Transmitter frequency	10525 MHz
	Transmitter power	~ 250 mW
	Antenna gain	-
	Warming up	Not required
	Base length (and tolerance)	-
OPERATION	General description	The frequency shift of the received signal is proportional to the radial velocity of the projectile. To obtain this frequency shift, the emitted and received signals are mixed.
AMPLIFIERS	General description	-
CHRONOMETERS	Description	-
COUNTERS	Name	-
	Manufacturer	-
	Time base resolution	-
	Measuring base resolution	-
	Read out	-
	Number of counters	-
	Independence of counters	-
	Precision	-
	Crystal stability	-
	Crystal in temperature control oven	-

Table continues

SYSTEM SPECIFICATION SHEET	No.: A-3
	continued

Function	Specifications	
OUTPUT	General description	-
	Display	Display a): 5 digit numeric, giving muzzle velocity (V_0) in m/s with 0.1 m/s resolution. Drop of velocity (DV) in m/s/m at the muzzle. Velocity (Vx) at any distance within radar range. Time of flight (Tx) to point x. Rate of fire (R.o.F.) when the time between single rounds is shorter than 5s. Display b): 5 digit numeric giving round No for which V_0, DV, Vx, Tx and Rate-of-fire. is calculated.
METHOD OF CALCULATION OF THE VELOCITY	General description of the method used for the calculation of the velocity of a projectile at a specific point (e.g. initial velocity).	The muzzle velocity is automatically calculated by measuring the velocity in a number of points down the trajectory, making a least-square-fit and then extrapolate back to the muzzle. Means for providing geometric correction, transmitter frequency correction and possible trigger delay correction as well as indication for unreliable measurements are included.
SIMULATION	General description	Simulator test equipment for both checking velocity and R.o.F. accuracy is provided.
ESTIMATED ACCURACY	Velocity	Better than 0.1 %.
ERROR INDICATION	General description	Built-in test facilities assures error indication when equipment is not working perfectly.

Table continues

SYSTEM SPECIFICATION SHEET	No.: A-3
	continued

Function	Specifications		
APPLICATIONS FIELD OF USE	Calibre range		4 mm and upwards (also base bleed ammunition)
	Velocity range		45 m/s to 2200 m/s
	Elevation range		0° - 90°
	Adjustable trajectories of measurements		-
	Temperature range	Radar unit	-30 °C to +55 °C
		Display unit	-5 °C to +55 °C
	Rate-of-Fire		Any up till about 1500 rounds per minute (somewhat depending on muzzle flash)
	Projectile types		-
SPECIALS	-		-
RESTRICTIONS	-		When measuring on shells with discarding sabots option -02 (Fast Fourier Transformation) should be used.
INCOMPATIBLE	with		-
Table ends			

SYSTEM SPECIFICATION SHEET	No.: A-4
	-

SYSTEM used by	DNK

Function	Specifications	
DETECTOR	System	Photoelectric
	Type of detector	Sky screens
	Name	EO300 Wide-Angle Sky Screen
	Manufacturer (Country of Origin)	OPOS ELECTRONICS A/S DNK Terma Elektronik AS, DNK
	Transmitter frequency	-
	Transmitter power	-
	Antenna gain	-
	Warming up	-
	Base length (and tolerance)	Variable, normally 10000 mm ± 5 mm
OPERATION	General description	-
AMPLIFIERS	General description	The EO300 (wide angle (90°)) each includes single one channel input amplifier with both analogue and detected (digital) output.
CHRONOMETERS	Description	-
COUNTERS	Name	CC2000 VM (or equivalent units)
	Manufacturer	OPOS Electronics A/S, DNK
	Time base resolution	0.1 µs
	Measuring base resolution	1 mm
	Read out	Velocity (m/s) and time (µs)
	Number of counters	1
	Independent counters No.	-
	Precision	-
	Crystal stability	± 0.02 %
	Crystal in temperature control oven	No
	Display	5 digits, resolution 0.1 m/s resp. 0.1 µs

Table continues

SYSTEM SPECIFICATION SHEET	No.: A-4
	continued

Function	Specifications		
OUTPUT	General description		-
	Display		-
METHOD OF CALCULATION OF THE VELOCITY	General description of the method used for the calculation of the velocity of a projectile at a specific point (e.g. initial velocity).		$v = \frac{baselength}{t}$ m/s; Centre point of measuring base may be selected according to practical conditions (calibre, muzzle flash etc.)
SIMULATION	General description		Signal generator with optical emitters. Field operation checked by momentarily interrupting the light falling on the detector.
ESTIMATED ACCURACY	Velocity		± 0.1 %
ERROR INDICATION	General description		-
APPLICATIONS FIELD OF USE	Calibre range		5.56 mm and up
	Velocity range		45 m/s to 2200 m/s
	Elevation range		Horizontal (decreased accuracy up to 45°)
	Adjustable trajectories of measure-ments		-
	Temperature range	Sky screens	- 20 °C to + 55 °C
		Velocity meter	- 5 °C to + 55 °C
	Rate-of-Fire		2000 rounds pm. Minimum 0.2 ms interval between stop signal and next start trigger. VM allows 380 rounds to be stored in the memory allowing up to 380 rounds to be fired in a salvo.
	Projectile types		-
SPECIALS	-		-
RESTRICTIONS	The equipment can not be used at		Low light conditions; Rain; Snow. Indoor conditions unless illuminators type AI350 are used.
INCOMPATIBLE	with		-
Table ends			

SYSTEM SPECIFICATION SHEET	No.: A-5
	-

SYSTEM used by	DNK, GRC, ITA, TUR

Function	Specifications	
DETECTOR	System	Photoelectric
	Type of detector	Sky screens
	Name	EO 350 sky screen
	Manufacturer (Country of Origin)	OPOS ELECTRONICS A/S DNK Terma Elektronik AS, DNK
	Transmitter frequency	-
	Transmitter power	-
	Antenna gain	-
	Warming up	-
	Base length (and tolerance)	Variable, normally 10000 mm ± 5 mm
OPERATION	General description	-
AMPLIFIERS	General description	The EO 350 (wide angle (45°)) each includes two detectors systems with separate detectors, amplifiers and analogue and detected (digital) outputs.
CHRONOMETERS	Description	-
COUNTERS	Name	CC2000 VM (or equivalent units)
	Time base resolution	0.1 µs
	Measuring base resolution	1 mm
	Read out	Velocity (m/s) and time (µs)
	Number of counters	2
	Independence of counters	All
	Precision	-
	Crystal stability	± 0.02 %
	Crystal in temperature control oven	No
	Display	5 digits, resolution 0.1 m/s resp. 0.1 µs

Table continues

SYSTEM SPECIFICATION SHEET	No.: A-5
	continued

Function	Specifications		
OUTPUT	General description		-
	Display		-
METHOD OF CALCULATION OF THE VELOCITY	General description of the method used for the calculation of the velocity of a projectile at a specific point (e.g. initial velocity).		v = 0.5 (baselength 1/ t1 + baselength 2/ t2) [m/s] Centre point of measuring base may be selected according to practical conditions (calibre, muzzle flash etc.)
SIMULATION	General description		Signal generator with optical emitters. Field operation checked by momentarily interrupting the height falling on the detector.
ESTIMATED ACCURACY	Velocity		± 0.1 %
ERROR INDICATION	General description		-
APPLICATIONS FIELD OF USE	Calibre range		5.56 mm and up
	Velocity range		45 m/s to 2200 m/s
	Elevation range		Horizontal (with decreased accuracy up to 45°)
	Adjustable trajectories of measurements		-
	Temperature range	Sky screens	-20 °C to + 55 °C
		Velocity meter	- 5 °C to + 55 °C
	Rate-of-Fire		2000 r.p.m. Minimum 0.2 ms interval between stop signal and next start trigger. VM allows 380 rounds to be stored in the memory allowing up to 380 rounds to be fired in a salvo.
	Projectile types		-
SPECIALS	-		-
RESTRICTIONS	The equipment can not used at		Low light conditions; rain, snow Indoor conditions unless illuminators type AI350 are used.
INCOMPATIBLE	with		-
Table ends			

SYSTEM SPECIFICATION SHEET	No.: A-6
	-

SYSTEM used by	DNK

Function	Specifications	
DETECTOR	System	Photoelectric
	Type of detector	Lightscreen with fixed base (infrared)
	Name	EV120 IR Reflex System
	Manufacturer (Country of Origin)	OPOS ELECTRONICS A/S DNK Terma Elektronik AS, DNK
	Transmitter frequency	-
	Transmitter power	-
	Antenna gain	-
	Warming up	-
	Base length (and tolerance)	2 m ± 1 mm
OPERATION	General description	-
AMPLIFIERS	General description	Each transducer includes one optical detector, one amplifier and one level detector giving out a 15 volt digital pulse. This system can therefore be used with a variety of counters, actually the CC2000 VM described below is used.
CHRONOMETERS	Description	-
COUNTERS	Name	CC2000 VM (or equipment units)
	Time base resolution	0.1 µs
	Measuring base resolution	1 mm
	Read out	Velocity (m/s) and time (µs)
	Number of counters	1 per system
	Independence of counters	-
	Precision	-
	Crystal stability	± 0.02 %
	Crystal in temperature control oven	No
	Display	5 digits, resolution 0.1 m/s resp. 0.1 µs

Table continues

SYSTEM SPECIFICATION SHEET	No.: A-6
	continued

Function	Specifications		
OUTPUT	General description		-
	Display		-
METHOD OF CALCULATION OF THE VELOCITY	General description of the method used for the calculation of the velocity of a projectile at a specific point (e.g. initial velocity).		v = baselength / t [m/s]. Centre point of measuring base may be selected according to practical conditions (calibre, muzzle flash etc.)
SIMULATION	General description		Signal generator with optical emitters. Field operation checked by momentarily interrupting the light falling on the detector.
ESTIMATED ACCURACY	Velocity		± 0.1 %
	Probable errors		-
ERROR INDICATION	General description		-
APPLICATIONS FIELD OF USE	Calibre range		5.56 mm to 40 mm
	Velocity range		45 m/s to 2200 m/s
	Elevation range		Horizontal only
	Adjustable trajectories of measurements		-
	Temperature range	Sky screens	- 20 °C to + 55 °C
		Velocity meter	- 5 °C to + 55 °C
	Rate-of-Fire		2000 r.p.m. Minimum 0.2 ms interval between stop signal and next start trigger. Velocity Meter allows 380 rounds to be stored in the memory allowing up to 380 rounds to be fired in a salvo.
	Projectile types		-
SPECIALS	-		-
RESTRICTIONS	-		Outdoor use maintains accuracy only when the optical system is covered.
INCOMPATIBLE	with		-
Table ends			

SYSTEM SPECIFICATION SHEET	No.: A-7
	-

SYSTEM used by	DNK

Function	Specifications	
DETECTOR	System	Photoelectric
	Type of detector	Light screen with fixed base
	Name	EV 100 Photocell Transducer System
	Manufacturer (Country of Origin)	OPOS ELECTRONICS A/S, DNK Terma Elektronik AS, DNK
	Transmitter frequency	-
	Transmitter power	-
	Antenna gain	-
	Warming up	-
	Base length (and tolerance)	2 m ± 0.5 mm, the two bases are of the same length
OPERATION	General description	-
AMPLIFIERS	General description	The “start” and “stop” transducer both include two independent detectors and amplifiers. The detector circuitry is included in the Velocity Meter (model CC2000, see below).
CHRONOMETERS	Description	-
COUNTERS	Name	CC2000 VM (or equivalent units)
	Manufacturer	OPOS ELECTRONICS A/S, DNK Terma, DNK
	Time base resolution	0.1 µs
	Measuring base resolution	1 mm
	Read out	Velocity (m/s) and time (µs)
	Number of counters	2 per system
	Independence of counters	Yes
	Precision	-
	Crystal stability	± 0.02 %
	Crystal in temperature control oven	no
	Display	5 digits, resolution 0.1 m/s resp. 0.1 µs

Table continues

SYSTEM SPECIFICATION SHEET	No.: A-7
	continued

Function	Specifications		
OUTPUT	General description		-
	Display		-
METHOD OF CALCULATION OF THE VELOCITY	General description of the method used for the calculation of the velocity of a projectile at a specific point (e.g. initial velocity).		v = 0.5 (baselength 1/ t1 + baselength 2/ t2) [m/s] Centre point of measuring base may be selected according to practical conditions (calibre, muzzle flash etc.)
SIMULATION	General description		Signal generator with optical emitters. Field operation checked by momentarily interrupting the light falling on the detector.
ESTIMATED ACCURACY	Velocity		± 0.1 %
	Probable errors		
ERROR INDICATION	General description		-
APPLICATIONS FIELD OF USE	Calibre range		5.56 mm to 40 mm
	Velocity range		45 m/s to 2200 m/s
	Elevation range		Horizontal only
	Adjustable trajectories of measurements		-
	Temperature range	Sky screens	-20 °C to +55 °C
		Velocity meter	- 5 °C to +55 °C
	Rate-of-Fire		2000 r.p.m. Minimum 0.2 ms interval between stop signal and next start trigger. Velocity Meter allows 380 rounds to be stored in the memory allowing up to 380 rounds to be fired in a salvo.
	Projectile types		-
SPECIALS	-		-
RESTRICTIONS	-		Outdoor use maintains accuracy only when the optical system is covered.
INCOMPATIBLE	with		-
Table ends			

SYSTEM SPECIFICATION SHEET	No.: A-8
	-

SYSTEM used by	CZE, DEU, DNK, ESP, GBR, ITA, NOR, USA

Function	Specifications	
DETECTOR	System	Electromagnetic
	Type of detector	Doppler Radar
	Name	DR 5000 Velocity Analyzer
	Manufacturer (Country of Origin)	Terma Elektronik AS, DNK
	Transmitter frequency	10525 GHz (X-Band) or 2630 GHz (S-Band) (see paragraph “METHOD OF CALCULATION…”)
	Transmitter power	0.2 W minimum
	Antenna gain	-
	Warming up	Not required
	Base length (and tolerance)	-
OPERATION	General description	The frequency shift of the received signal is proportional to the radial velocity of the projectile (the Doppler Principle). To obtain this frequency shift, the emitted and received signals are mixed, and the resulting signal is digitised and processed online by means of a FFT.
AMPLIFIERS	General description	-
CHRONOMETERS	Description	-
COUNTERS	Time base resolution	-
	Measuring base resolution	-
	Read out	-
	Number of counters	-
	Independence of counters	-
	Precision	-
	Crystal stability	-
	Crystal in temperature control oven	-
	Display	-

Table continues

SYSTEM SPECIFICATION SHEET	No.: A-8
	continued

Function	Specifications	
OUTPUT	General description	Graphical display of radial velocity versus time, of parallax corrected velocity versus time, and of least-squares-fit function used for calculation of muzzle velocity. The reliability of the measurements are indicated graphically by a status signal.
	Online display	Superimposed numerical display of: 1. Muzzle velocity (V_0) in m/s or feet/s with a resolution of 0.01 m/s or 0.01 feet/s. 2. Drop of velocity (V; retardation) at the muzzle in m/s/m or feet/s/feet. 3. Velocity (Vx) at a user selected distance x within the radar range. 4. Time-of-flight (Tx) to the user selected distance x. 5. Rate-of-Fire information if this mode is selected. Rate-of-Fire information includes rounds per second, average time between rounds, minimum time between rounds, maximum time between rounds, average muzzle velocity.
	Optional displays	The following graphs are available for display immediately after the firing: 1. Velocity versus time or distance. 2. Acceleration versus time or distance. 3. Distance versus time. 4. Signal-to-noise ratio versus time or distance. 5. Doppler signal versus time. 6. 3D-(Waterfall) plot of signal power versus velocity and time. The following tables are available for display immediately after the firing: 1. Report with data unit setup parameters and a listing of velocity, distance, acceleration, and signal-to-noise ratio as functions of time in a user defined time step. 2. Report with statistical information on a number of user selected rounds. This information includes average values and probable errors on muzzle velocities, muzzle retardations, Vx, and Tx. The individual measurement values are compared with the average values.
METHOD OF CALCULATION OF THE VELOCITY	General description of the method used for the calculation of the velocity of a projectile at a specific point (e.g. initial velocity).	The muzzle velocity is calculated automatically by measuring the velocity in a number of points down the trajectory, making a least-squares-fit, and extrapolation back to the muzzle.

Table continues

SYSTEM SPECIFICATION SHEET	No.: A-8
	continued

Function	Specifications		
METHOD OF CALCULATION OF THE VELOCITY CONTINUED			Means for providing geometric correction (parallax correction), transmitter frequency correction, and possible trigger delay correction are included. The actual transmitter frequency must be known and must be stable within 0.01 %.
SIMULATION	General description		Optional simulator test equipment for checking signal processing and velocity accuracy is available.
ESTIMATED ACCURACY	Velocity		Better than 0.1 percent.
ERROR INDICATION	General description		Built-in test facilities assure error indication when equipment is not working perfectly.
APPLICATIONS FIELD OF USE	Calibre range		4 mm and upwards including sub-calibre, finned projectiles, base burn ammunition, rockets, and rocket assisted projectiles.
	Velocity range		50 m/s to 3000 m/s.
	Elevation range		0° to 90°
	Adjustable trajectories of measurements		-
	Temperature range	Radar unit	-20 °C to + 55 °C
		Data unit	0 °C to + 40 °C
	Rate-of-Fire		Lower limit: Depends on circumstances. Upper limit: 10000 rounds per minute.
	Projectile types		-
SPECIALS	-		-
RESTRICTIONS	-		When used for rate-of-fire measure-ments an adequate external trigger (flash photocell) or microphone) must be used. For single round measurements an external trigger is recommended, but not required.
INCOMPATIBLE	with		-
Table ends			

SYSTEM SPECIFICATION SHEET	No.: A-9
	-

SYSTEM used by	GBR

Function	Specifications	
DETECTOR	System	Electro-magnetic
	Type of detector	Doppler antenna
	Name	Marcal MVMD
	Manufacturer (Country of Origin)	Marconi, GBR
	Transmitter frequency	-
	Transmitter power	0.04 W
	Antenna gain	-
	Warming up	-
	Base length (and tolerance)	-
OPERATION	General description	The frequency shift of the received signal is proportional to the radial velocity of the projectile. This signal is digitised and processed by FFT.
AMPLIFIERS	General description	-
CHRONOMETERS	Description	-
COUNTERS	Name	-
	Time base resolution	-
	Measuring base resolution	-
	Read out	-
	Number of counters	-
	Independence of counters	-
	Precision	-
	Crystal stability	-
	Crystal in temperature control oven	-
	Display	-

Table continues

SYSTEM SPECIFICATION SHEET	No.: A-9
	continued

Function	Specifications		
OUTPUT	General description		-
	Display		Muzzle velocity and corrected quadrant elevation are displayed.
METHOD OF CALCULATION OF THE VELOCITY	General description of the method used for the calculation of the velocity of a projectile at a specific point (e.g. initial velocity).		The muzzle velocity is calculated automatically and corrected for gun recoil.
SIMULATION	General description		-
ESTIMATED ACCURACY	Velocity		0.16 % at 100 m/s, 0.20 % at 1000 m/s
	Probable errors		-
ERROR INDICATION	General description		-
APPLICATIONS FIELD OF USE	Calibre range		50 mm and upwards
	Velocity range		100 m/s - 1000 m/s
	Elevation range		All operational
	Adjustable trajectories of measurements		All operational
	Temperature range	Sky screens	-
		Velocity meter	-
	Rate-of-Fire		-
	Projectile types		-
SPECIALS	-		-
RESTRICTIONS	-		Up to 30 rounds per minute.
INCOMPATIBLE	with		-
Table ends			

SYSTEM SPECIFICATION SHEET	No.: A-10
	-

SYSTEM used by	FRA

Function	Specifications	
DETECTOR	System	Single/Multiple Turn Solenoid Frames
	Type of detector	-
	Name	-
	Manufacturer (Country of Origin)	ETBS, FRA
	Transmitter frequency	-
	Transmitter power	-
	Antenna gain	-
	Warming up	-
	Base length (and tolerance)	-
OPERATION	General description	A conductor wound around an amagnetic frame defines a plane surface across which the magnetic field generated by a previously magnetised projectile induces a magnetic flux. The rapid variation of this flux caused by the movement of the projectile gives rise to a variable electro-motive force. That force generates an analogue signal whose polarity changes when the centre of the equivalent magnetic dipole passes through the plane of the coil. 2 identical frames are used for measuring the velocity.
	Useful field of measurement	20 cm x 20 cm (small calibres) 50 cm x 50 cm (medium calibres) 90 cm x 90 cm (large calibres)
	Base length	On “Torpedo” base, standard length 4 m. Other lengths are possible on suitable non-magnetic supports.
	Particular features	System with 2 independent channels allowing for double measurements. Permits selection of the number of turns (1, 10, 50 or 1.50 according to the model).
	Operating temperature	-20 °C to +50 °C

Table continues

SYSTEM SPECIFICATION SHEET	No.: A-10
	continued

Function	Specifications	
AMPLIFIERS	General description	Detects the analogue signal's passage through 0 after amplification; supplies a calibrated synchronous pulse.
	AMPLI 74	4 independent channels. Gain adjustable (4 positions). Pass-band: 1 Hz - 40 kHz. Triggering by detection of 0. Incorporated duration simulator.
CHRONOMETERS	Description	Triggered by the pulses supplied by the amplifier.
	CALVI 73 (measurement of individual shots)	1 channel. Time base: 1 MHz and 10 MHz. Base length: adjustable by thumb-wheels. Incorporates stop and automatic reset functions. Outputs: time and velocity (5-digit LED display), BCD output.
	CALVI 90 (measurement of shots and bursts)	1 channel. Time base 10 MHz. Base length programmable. Stop and automatic reset functions incorporated. Capacity: 8000 shots. Programming keyboard incorporated. Outputs: time and velocity (4x20-character plasma display), HP-IB bus.
	CHROCAL (shots and bursts)	4 independent channels. Time base 10 MHz. Base length programmable. Stop and automatic reset functions incorporated. Capacity: 500 shots. Remote programming keyboard. Outputs: number of shots (3-digit LED display), time and velocity (printer), HP-IB bus.
COUNTERS	Name	-
	Time base resolution, µs	-
	Measuring base resolution, mm	-
	Read out	-
	Number of counters	-

SYSTEM SPECIFICATION SHEET	No.: A-10
	continued

Function	Specifications		
COUNTERS CONTINUED	Independence of counters		-
	Precision		-
	Crystal stability		-
	Crystal in temperature control oven		-
	Display		-
OUTPUT	General description		-
	Display		-
METHOD OF CALCULATION OF THE VELOCITY	General description of the method used for the calculation of the velocity of a projectile at a specific point (e.g. initial velocity).		Average velocity over the base length $v_m = dx / dt$ assigned to the mid-point of the measuring base.
SIMULATION	General description		Duration simulator with amplifier 74.
ESTIMATED ACCURACY	Velocity		Rel. uncertainty regarding calculated velocity: 0.1 % to 0.3 % (at 2s).
ERROR INDICATION	General description		-
APPLICATIONS FIELD OF USE	Calibre range		5 mm to 155 mm
	Velocity range		80 m/s to 2000 m/s
	Elevation range		Horizontal or low-angle (< 20°) fire.
	Adjustable trajectories of measurements		-
	Temperature range	Sky screens	-
		Velocity meter	-
	Rate-of-Fire		Individual shots or bursts.
	Projectile types		Any type with or without tracer.
SPECIALS	-		-
RESTRICTIONS	-		-
INCOMPATIBLE	with		Non-magnetisable projectiles which can not be fitted with a permanent magnet; sub-calibre munitions (projectiles launched by sabots); unfavourable magnetic environments (stormy weather, proximity of metallic masses).
Table ends			

SYSTEM SPECIFICATION SHEET	No.: A-11
	-

SYSTEM used by	DEU, ESP, FIN, FRA, ITA, NOR, USA

Function	Specifications	
DETECTOR	System	Photoelectric
	Type of detector	Sky-screens with variable base (a) CINTEL H ; (b) GP80/SW90
	Name	Photo basis
	Manufacturer (Country of Origin)	(a) Milligan, GBR; (b) Weibel, DNK
	Transmitter frequency	-
	Transmitter power	-
	Antenna gain	-
	Warming up	-
	Base length (and tolerance)	(a, b) 30000 mm ± 5 mm (b) 20000 mm ± 5 mm
OPERATION	General description	-
AMPLIFIERS	General description	2 one-channel input amplifiers in each of both counters with trigger-level adjustment.
CHRONOMETERS	Description	-
COUNTERS	Name	Drello BAL 3004 WEIBEL W630/W640, Hude IF350 or equivalent systems
	Time base resolution	0.1 µs
	Measuring base resolution	-
	Read out	-
	Number of counters	2
	Independence of counters	Yes
	Precision	1 count = 10^{-7} s.
	Crystal stability	5 10^{-6} from -25 °C to + 55 °C
	Crystal in temperature control oven	Yes
	Display	Time intervals in 0.1 ms on LED 6 or 9 decades in line read-out.

Table continues

SYSTEM SPECIFICATION SHEET	No.: A-11
	continued

Function	Specifications		
OUTPUT	General Description		-
	Display		-
METHOD OF CALCULATION OF THE VELOCITY	General description of the method used for the calculation of the velocity of a projectile at a specific point (e.g. initial velocity).		The centre of the bases is at x m in front of the gun-muzzle or at another place, i.e. ($v = v_x$ in m/s) v = 0.5 (baselength 1/ t1 + baselength 2/ t2) [m/s]
SIMULATION	General description		Signal Generator. Moving hand over the detectors. The correct function of the counters is checked by Puls-Generator and calibration with normal frequency.
ESTIMATED ACCURACY	Velocity		0.10% (Flash X-ray assured)
	Probable errors		-
ERROR INDICATION	General description		-
APPLICATIONS FIELD OF USE	Calibre range		15 mm and larger
	Velocity range		50 m/s and up to 1750 m/s
	Elevation range		Horizontal
	Adjustable trajectories of measurements		-
	Temperature range	Sky screens	-25 °C to + 55 °C
		Velocity meter	-
	Rate-of-Fire		-
	Projectile types		KE finned with/without tracer
SPECIALS	-		-
RESTRICTIONS	The equipment can not used at		Darkness; artificial illumination, strong rain or snow. For Weibel (DNK) + discarding sabots (except with protectors) base burn projectiles.
INCOMPATIBLE	with		-
Table ends			

SYSTEM SPECIFICATION SHEET	No.: A-12
	-

SYSTEM used by	DEU, TUR

Function	Specifications	
DETECTOR	System	Magnetic
	Type of detector	Monospires
	Name	Spulenbasis
	Manufacturer (Country of Origin)	WTD 91 and Industry, Germany
	Transmitter frequency	-
	Transmitter power	-
	Antenna gain	-
	Warming up	-
	Base length (and tolerance)	6000 mm ± 1 mm 4000 mm ± 1 mm
OPERATION	General description	-
AMPLIFIERS	General description	2 one-channel input amplifiers in each of both counters
CHRONOMETERS	Description	-
COUNTERS	Name	Weibel W630 or W640 or Hude IF3 or OPOS 200
	Time base resolution	0.1 µs
	Measuring base resolution	-
	Read out	-
	Number of counters	2
	Independence of counters	Yes
	Precision	-
	Crystal stability	$5\ 10^{-6}$ from -25 °C to + 55 °C
	Crystal in temperature control oven	Yes
	Display	Time intervals in 0.1 µs
OUTPUT	General description	-
	Display	-

Table continues

SYSTEM SPECIFICATION SHEET	No.: A-12
	continued

Function	Specifications		
METHOD OF CALCULATION OF THE VELOCITY	General description of the method used for the calculation of the velocity of a projectile at a specific point (e.g. initial velocity).		The centre of each of both bases is x metres in front of the gun-muzzle therefore $v_X = \frac{1}{2}(\frac{6}{t1} + \frac{4}{t2})[m/s]$
SIMULATION	General description		The correct function of the complete system is checked by inducting a signal in the spires, the correct function of the counters is checked by Puls-Generator and calibration with normal frequency.
ESTIMATED ACCURACY	Velocity		0.1 %
ERROR INDICATION	General description		-
APPLICATIONS FIELD OF USE	Calibre range		7.62 mm - 203 mm
	Velocity range		100 m/s - 1700 m/s
	Elevation range		Up to 65°
	Adjustable trajectories of measurements		-
	Temperature range	-	-25 °C to +55 °C
		-	-
	Rate-of-Fire		-
	Projectile types		-
SPECIALS	-		-
RESTRICTIONS	The equipment can not be used at		Discarding sabots (only with protective shields); shells without a paramagnetic ingredient in the metallurgic compo-sition
INCOMPATIBLE	with		-
Table ends			

SYSTEM SPECIFICATION SHEET	No.: A-13
	-

SYSTEM used by	GBR, ITA

Function	Specifications	
DETECTOR	System	Photo-electric
	Type of detector	Sky-screen with variable base
	Name	Photo-cell counter chronometer ITA: Type H, type E, Type EM detector screen
	Manufacturer (Country of Origin)	Royal Armament Research and Development Establishment ITA: Milligan Electronics Limited (GBR)
	Transmitter frequency	-
	Transmitter power	-
	Antenna gain	-
	Warming up	-
	Base length (and tolerance)	30000 mm ± 1 mm; ITA: variable
OPERATION	General description	-
AMPLIFIERS	General description	6 single channel amplifiers each providing a choice of base or nose operation. ITA: 2 one-channel input amplifiers in each counter with trigger level adjustment and choice of base or nose operation.
CHRONOMETERS	Description	-
COUNTERS	Name	Velocity and Fire Rate Analyzer VFR 421. Milligan Microsecond Counter chrono-meter MCC Type 222
	Manufacturer	VFR 421: SABRE Computers Int. Ltd (GBR) MCC Type 222 : MILLIGAN ELECTRONICS (GBR)
	Time base resolution	1 µs
	Measuring base resolution	-
	Read out	-

Table continues

SYSTEM SPECIFICATION SHEET	No.: A-13
	continued

Function	Specification	
CONTERS *CONTINUED*	Number of counters	VFR 421: 3 MCC Type 222: 1
	Counter Position	1 count = 10^{-6} s
	Independence of counters	Yes
	Precision	-
	Crystal stability	VFR 421: ± 0.3 ppm MCC Type 222: 2 parts in 10^6/week
	Crystal in temperature control oven	-
	Display	Digital readout - 6 decades
OUTPUT	General description	
	Display	The times are displayed on counters. ITA: VFR 421: the velocities are displayed on counters. Number of fired shots: mean and standard deviation of velocity and rate of fire for chosen groups. ITA: MCC type 222: the times are displayed on counters.
METHOD OF CALCULATION OF THE VELOCITY	General description of the method used for the calculation of the velocity of a projectile at a specific point (e.g. initial velocity).	The observed velocities are calculated from the individual channel times and corresponding screen base lengths. These are then averaged to give the reported OV. Rejection is based on a total spread in velocities of not greater then 0.1 % of the average OV.
SIMULATION	General description	Equipment testing is carried out by means of an electronic pulse test and a manual wave test *). ITA: external signal generator. *) i.e. momentarily interrupting the lights falling on the detector.
ESTIMATED ACCURACY	Velocity	Velocity is accurate to 0.1 %.
ERROR INDICATION	General description	-

Table continues

SYSTEM SPECIFICATION SHEET	No.: A-13
	continued

Function	Specifications		
APPLICATIONS FIELD OF USE	Calibre range		7.62 mm and up
	Velocity range		45 m/s - 2500 m/s
	Elevation range		0° - 45°, covered by two sky-screens. ITA: horizontal (type H); 5° - 45° (type E); 45 ° - 60° (type EM)
	Adjustable trajectories of measurements		-
	Temperature range	sky screens	Temperate climates only ITA: 0 °C to + 55 °C
		velocity meter	-
	Rate-of-Fire	VFR 421	max shot number in a burst 200
			max rate of fire: 6000 burst/min
			min rate of fire: 60 burst/min
	Projectile types		-
SPECIALS	-		-
RESTRICTIONS			Skylight below 0.003 candles/cm^2 Artificial illumination Strong rain and snow Discarding sabots (except with protectors) Muzzle to first screen < 15 metres (muzzle flash; generally, the larger the calibre, the higher the first screen distance).
INCOMPATIBLE	with		-
Table ends			

SYSTEM SPECIFICATION SHEET		No.: A-14
		-
SYSTEM used by (at least one of them)	**DEU, DNK, GBR, NLD, SWE, USA**	
Function	**Specifications**	
DETECTOR	System	Electromagnetic
	Type of detector	Doppler Radar
	Name	1. SL-520P Doppler Radar System 2. SL-525 P Doppler Radar System 3. SL-15028P Doppler Radar System 4. SL 30031P Doppler Radar System
	Manufacturer (Country of Origin)	Weibel Scientific A/S, DNK
	Transmitter frequency	X-band 10.400 to 10.600 GHz
	Transmitter power	1. 0.4 Watt 2. 0.4 Watt 3. 15 Watt 4. 30 Watt
	Antenna gain / lobe	1. 20 dB / 19.0° x 9.0° nominal 2. 25 dB / 9.0° x 9.0° nominal 3. 28 dB / 9.0° x 4.5° nominal 4. 31 dB / 4.5° x 4.5° nominal
	Polarisation	Vertical
	Warming up	-
	Base length (and tolerance)	-
OPERATION	General description	Microwaves transmitted towards the projectile are partially reflected by it. The reflected frequency has been slightly modified by the Doppler effect due to the radial velocity of the projectile. Low pass filters (cut off frequency 230 kHz),are applied before digitizing of the Doppler signal by a 12 bit A/D converter. The digitized Doppler signal are stored for further analysis.
AMPLIFIERS	General description	-
PROCESSING UNIT	General description	The processing and analysis are performed in the WinDopp program, running on a Windows PC. The digitized Doppler signal are automatically transferred to the IC-700 processing computer (standard Window PC with WinDopp analysis software) for further analysis.

Table continues

SYSTEM SPECIFICATION SHEET	No.: A-14
	continued

Function	Specifications	
PROCESSING UNIT CONTINUED		The WinDopp program automatically performs a FFT (32 – 4096 points or higher are used in the FFT) based analysis of the recorded signal, and extract the velocity profile from the recorded signal. Overlap FFT are possible. The Muzzle Velocity is calculated based on a curve fit to the measured Velocity profile – and displayed to the operator. Timing of measurement Continues recording based on the specified velocity range.
COUNTERS	Name	-
	Time base resolution	-
	Measuring base resolution	-
	Read out	-
	Number of counters	-
	Independence of counters	-
	Precision	-
	Crystal stability	-
	Crystal in temperature control oven	-
	Display	-
OUTPUT	General description	-
	Display of	a. Colour Doppler spectrum (DTI) b. Velocity track information c. Velocity vs. Time d. Velocity vs slant distance e. Slant distance vs. time f. Acceleration vs time g. Acceleration vs Slant distance h. More user specified displays
	Data input	
	Displayed data	
	Printer / Plotter	All the above displays are available as hardcopies or numerical lists.

Table continues

SYSTEM SPECIFICATION SHEET	No.: A-14
	continued

Function	Specifications		
METHOD OF CALCULATION OF THE VELOCITY	General description of the method used for the calculation of the velocity of a projectile at a specific point (e.g. initial velocity).		Mean radial velocity Vr = ($f_{Doppler}$ * C)/ (2 * $f_{Transmit}$) over the duration of each FFT window. The velocity measured is assigned to the mid point of the FFT window
	Initial Velocity		By extrapolation to the muzzle exit time of a polynomial regression after correction for parallax and elimination of outlayer readings
SIMULATION	General description		-
ESTIMATED ACCURACY	Velocity		Relative uncertainty regarding measured radial velocity: < 0.1%
ERROR INDICATION	General description		-
APPLICATIONS FIELD OF USE	General description		Individual or burst
	Calibre range		5 mm to 203 mm conventional and with base bleed, tracer and rocket assist
	Velocity range		20 m/s to 3000 m/s
	Elevation range in degrees		Horizontal or angled firing (0° - 90°)
	Adjustable trajectories of measurements		-
	Temperature range	Sky screens	-30 °C to + 50 °C
		Velocity meter	
	Rate-of-Fire		10000 rounds/min maximum
	Projectile types		All types with or without tracer, base bleed or rocket assist, including sabot rounds
SPECIALS	-		Stripline radar antenna with separate Transmitter and Receiver section. Internal Microphone or External trigger. Multiple target measurements possible (i.e. sabot rounds)
RESTRICTIONS	-		.
INCOMPATIBLE	with		Unfavourable atmospheric conditions (heavy rain)
Table ends			

SYSTEM SPECIFICATION SHEET	No.: A-15
	-

SYSTEM used by	NOR

Function	Specifications	
DETECTOR	System	Electro magnetic
	Type of detector	Doppler antenna
	Name	MVI MK 3 (Muzzle Velocity Indicator Mark 3)
	Manufacturer (Country of Origin)	AWA Defence Industries Pty Ltd
	Transmitter frequency	9775 GHz ± 2 MHz
	Transmitter power	200 mW (Continues wave)
	Antenna gain	-
	Warming up	-
	Base length (and tolerance)	-
OPERATION	General description	The measurement cycle is initiated when an accelerometer, mounted in the Radar Unit defects gun acceleration due to charge ignition. A transmitted microwave signal is sent along the projectile path. The reflected Doppler signal is Doppler shifted by an amount, proportional to the velocity of the projectile. The difference in frequency is passed continuously to the processor which computes the velocity history of the projectile and, hence, derives its muzzle velocity.
AMPLIFIERS	General description	-
CHRONOMETERS	Description	-
COUNTERS	Name	-
	Time base resolution, µs	-
	Measuring base resolution, mm	-
	Read out	-
	Number of counters	-

Table continues

SYSTEM SPECIFICATION SHEET	No.: A-15
	continued

Function	Specifications	
COUNTERS CONTINUED	Independence of counters	-
	Precision	-
	Crystal stability	-
	Crystal in temperature control oven	-
	Display	-
OUTPUT	General description	-
	Display	2 line by 20 character liquid crystal.
	Data input	4 * 7 keyboard for system operation, control and data input
	Displayed data	True or reduced muzzle velocity of the last N numbers of rounds fired (up to 512 rounds), and average for a specified number of rounds.
	Calculation	The muzzle velocity is calculated by extrapolation of the flight function best fitting the measured data (64 samples), after making parallax corrections for the Radar Unit offset distance from the gun barrel centreline. First measurement starts approximately one metre in front of the gun barrel. The measurement base is approximately one metre (64 / 2).
METHOD OF CALCULATION OF THE VELOCITY	General description of the method used for the calculation of the velocity of a projectile at a specific point (e.g. initial velocity).	-
SIMULATION	General description	Input from PC for training purpose. The system has a built-in test facility which provides unambiguous indication of fault location to the replacement module level.
ESTIMATED ACCURACY	Probable errors	Probable errors not worse than ± 0.05 %.
ERROR INDICATION	General description	-

Table continues

SYSTEM SPECIFICATION SHEET	No.: A-15
	continued

Function	Specifications		
APPLICATIONS FIELD OF USE	Calibre range		20 mm and up
	Velocity range		50 m/s - 2400 m/s
	Elevation range		-
	Adjustable trajectories of measurements		-
	Temperature range	Sky screens	- 40 °C to + 50 °C
		Velocity meter	-
	Rate-of-Fire		Up to 600 rounds/min
	Projectile types		-
SPECIALS	-		-
RESTRICTIONS	-		The equipment is not tested for rocket Assisted Projectiles.
INCOMPATIBLE	with		-
Table ends			

SYSTEM SPECIFICATION SHEET	No.: A-16
	-

SYSTEM used by	ESP, GRC

Function	Specifications	
DETECTOR	System	Electromagnetic
	Type of detector	Doppler Radar
	Name	DR582 Velocity/Trajectory Analyzer
	Manufacturer (Country of Origin)	TERMA Elektronik AS, DNK
	Transmitter frequency	10490 GHz (X-Band) (nominal), see paragraph “Calculation”.
	Transmitter power	150 mW (minimum)
	Antenna gain	-
	Warming up	Not required
	Base length (and tolerance)	-
OPERATION	General description	The frequency of the received signal is proportional to the radial velocity of the projectile (the Doppler Principle). To obtain this frequency shift, part of the emitted signal, and the resulting signal is amplified and filtered before the frequency (velocity) is analysed by the FFT analysing system, both included in the DR582 Data Unit.
COMPUTING PART	Hardware	HP9000 series (320)
	Software	TERMA Elektronik S/A
	Description	Takes data in from the DR582 Data Unit and calculates: - muzzle velocity - velocity / burn-out for rockets - time to burn for rockets calculates and plots - radial velocity vs time or slant - acceleration vs time or slant - cd vs Mach - altitude vs distance - velocity vs distance / time - inclination of trajectory

Table continues

SYSTEM SPECIFICATION SHEET	No.: A-16
	continued

Function	Specifications	
AMPLIFIERS	General description	The input amplifiers are the interconnecting elements between two antennas and the filter module. To be able to store the analogue signal from the antennas and use them later, the amplifier is provided with outputs for an eventual analogue tape recorder and inputs to accept the replayed signals.
	Band-with	50 Hz - 210 KHz
	Gain	DIFF IN input to SINGLE OUT -30dB to 0dB DIFF IN input to AMP OUT -30dB to +40dB REPLAY input to AMP OUT 0dB to +40dB.
CHRONOMETERS	Description	-
COUNTERS	Name	-
	Time base resolution	-
	Measuring base resolution	-
	Read out	-
	Number of counters	-
	Independence of counters	-
	Precision	-
	Crystal stability	-
	Crystal in temperature control oven	-
	Display	-
OUTPUT	General description	Output plots of calculated data.
	Display	-
METHOD OF CALCULATION OF THE VELOCITY	General description of the method used for the calculation of the velocity of a projectile at a specific point (e.g. initial velocity).	The muzzle velocity is automatically calculated by measuring the velocity in a number of points (max. 2048) along the trajectory, making least-squares-fit, and then extrapolated back to muzzle.

Table continues

SYSTEM SPECIFICATION SHEET	No.: A-16
	continued

Function	Specifications		
METHOD OF CALCULATION OF THE VELOCITY *CONTINUED*	-		Means for providing geometric correction (parallax correction), transmitter frequency correction, and possible trigger delay correction are included. The actual transmitter frequency must be known and must be stable within 0.01 %.
SIMULATION	General description		-
ESTIMATED ACCURACY	Velocity		Better than 0.1 %
	Probable errors		-
ERROR INDICATION	General description		-
APPLICATIONS FIELD OF USE	Calibre range		5.56 mm to 203 mm
	Velocity range		50 m/s to 2500 m/s
	Elevation range		-5 °C to + 55 °C
	Adjustable trajectories of measurements		-
	Temperature range	Sky screens	- 20 °C to + 55 °C
		Velocity meter	-
	Rate-of-Fire		Lower limit: depends on circumstances. Upper limit: 300 rounds per minute
	Projectile types		-
SPECIALS	-		-
RESTRICTIONS	-		The equipment can not be used with thunderstorms and heavy rain. FFT processing should be used when measuring on shells with discarding sabots or other moving objects in the main lobe of the antenna.
INCOMPATIBLE	with		-
Table ends			

SYSTEM SPECIFICATION SHEET	No.: A-17
	-

SYSTEM used by	CZE, DEU, ESP, FIN, FRA, GBR, ITA, NLD, NOR, TUR, USA

Function	Specifications	
DETECTOR	System	Electromagnetic
	Type of detector	Doppler Radar
	Name	MVRS W-700 (W-680) and W-1000 MV Radar Systems
	Manufacturer (Country of Origin)	Weibel Scientific, DNK
	Transmitter frequency	10400 GHz
	Transmitter power	5 W (W-700), 15 W (W-1000)
	Antenna gain / lobe	20 dB / 10° x 20° (W-700) 29 db / 10° x 20° (W-1000)
	Polarisation	Rectilinear H of V depending on the orientation.
	Warming Up	-
	Base length (and tolerance)	-
OPERATION	General description	Microwaves transmitted towards the projectile are partially reflected by it. On return their frequency has been slightly modified by the Doppler effect due to the radial velocity of the projectile. A processing system extracts this frequency shift (proportional to the perceived radial velocity) from the carrier frequency.
AMPLIFIERS	General description	-
CHRONOMETERS	Description	-
COUNTERS	Name	-
	Time base resolution	-
	Measuring base resolution	-
	Read out	-
	Number of counters	-
	Independence of counters	-
	Precision	-
	Crystal stability	-

Table continues

SYSTEM SPECIFICATION SHEET	No.: A-17
	continued

Function	Specifications	
COUNTERS CONTINUED	Crystal in temperature control oven	-
	Display	-
PROCESSING UNIT	General Description	Works in frequency mode (search for the Doppler line in the frequency spectrum obtained by FFT processing). Low pass filter incorporated (cut-off frequency 140 kHz). Sampling frequency f_s: 333 Hz to 666 kHz. Analogue-digital conversion: 12 bits. Number of FFT points: 32 to 4096. Timing of measurements: Continues mode: timing equal to the duration of the time window for acquisition N/f_s (with possibility of zooming by overlap). Sequential mode: timing programmable up to 3 s.
OUTPUT	General Description	-
	Display of:	1. 2-D and 3-D waterfall plot; 2. velocity vs time (measuring points and polynomial fit); 3. velocity vs slant distance; 4. slant distance vs time; 5. acceleration vs time; 6. acceleration vs slant distance 7. drag coefficient C_d vs time; 8. drag coefficient C_d vs Mach number; 9. Doppler signal vs time.
	Printer/Plotter of:	1. time, radial velocity, slant distance, acceleration, retardation, signal/noise ration; 2. time, radial velocity, tangential velocity (in Mach), slant distance, drag coefficient, signal/noise ration; 3. muzzle velocity, acceleration and retardation; 4. velocity calculator functions; 5. regression analysis information 6. W-700M parameters.

Table continues

SYSTEM SPECIFICATION SHEET	No.: A-17
	continued

Function	Specifications	
METHOD OF CALCULATION OF THE VELOCITY	General description of the method used for the calculation of the velocity of a projectile at a specific point (e.g. initial velocity).	Mean radial velocity $v_r = f_d$ ½ over the duration of the acquisition window. The velocity measured is assigned to the mid-point of the acquisition window.
	Initial velocity calculation	By extrapolation to the origin of a polynomial regression after correction for parallax and elimination of outlying values.
SIMULATION	General description	-
OVERALL ACCURACY	Velocity	Relative uncertainty regarding measured radial velocity: 0.1 % (at 2 s)
ERROR INDICATION	General description	-
APPLICATIONS FIELD OF USE	General description	Individual shots or burst (a single measuring point pp in burst mode)
	Calibre range	5 mm to 155 mm
	Velocity range	20 m/s to 2000 m/s
	Elevation range	Horizontal or angled fire.
	Adjustable trajectories of measurements	-
	Temperature range	-30 °C to + 50 °C
		-
	Rate-of-Fire	10000 rounds/minute
	Projectile types	All types with or without tracer.
SPECIALS		Single antenna strip line radar. Microphone for triggering from muzzle noise incorporated. Multiple target tracking possible.
RESTRICTIONS		-
INCOMPATIBLE	with	Unfavourable atmospheric condition (heavy rain). Large metallic masses in the field of the antennas.
Table ends		

SYSTEM SPECIFICATION SHEET	No.: A-18
	-

SYSTEM used by	FRA

Function	Specifications	
DETECTOR	System	Infrared optical barriers.
	Type of detector	BOIR LG 500 + BOIR LG 1000
	Name	-
	Manufacturer (Country of Origin)	ETBS, FRA
	Transmitter frequency	-
	Transmitter power	-
	Antenna gain	-
	Warming up	-
	Base length (and tolerance)	On “Torpedo” base, standard length 4 m. Other lengths are possible on suitable supports.
OPERATION	General description	A luminous plane generated by an incandescent source (linear-coiled lamp) is partially occulted by the passage of the projectile. A system of photodiodes detects the variation in the luminous flux and supplies an analogue signal, image of the projectile profile. Two identical barriers are used to measure the velocity.
	Useful field of measurement	LG 500: 50 cm x 40 cm LG 1000: 80 cm x 70 cm
AMPLIFIERS	General description	AMPLI 84: Generates calibrated pulses by thresholding the analogue signal. 4 independent channels. Adjustable gain (3 positions). Pass-band 30 Hz - 200 kHz. Triggering threshold continuously adjustable. Detection of cap, base or tracer. Incorporated duration simulator.

Table continues

SYSTEM SPECIFICATION SHEET	No.: A-18
	continued

Function	Specifications	
CHRONOMETERS	Description	Triggered by the pulses supplied by the amplifier.
	CALVI 73 (measurement of individual shots)	1 channel. Time base 1 MHz and 10 MHz. Base length adjustable by thumbwheels. Stop and automatic reset functions incorporated. Outputs: time and velocity (5-digit LED display), BCD output.
	CLVI 90 (measurement of shots and bursts)	1 channel. Time base 10 MHz. Base length programmable. Stop and automatic reset functions incorporated. Capacity: 8000 shots. Incorporated programming keyboard. Outputs: time and velocity (4x20-character plasma display), HP-IB bus.
	CHROCAL (shots and bursts)	4 independent channels. Time base 10 MHz. Programmable base length. Stop and automatic reset functions incorporated. Capacity: 500 shots. Remote programming keyboard. Outputs: number of shots (3-digit LED display), time and velocity (printer), HP-IB bus.
COUNTERS	Name	-
	Time base resolution	-
	Measuring base resolution	-
	Read out	-
	Number of counters	-
	Independence of counters	-
	Precision	-
	Crystal stability	-
	Crystal in temperature control oven	-
	Display	-

Table continues

SYSTEM SPECIFICATION SHEET	No.: A-18
	continued

Function	Specifications		
OUTPUT	General description		-
	Display		-
METHOD OF CALCULATION OF THE VELOCITY	General description of the method used for the calculation of the velocity of a projectile at a specific point (e.g. initial velocity).		Average velocity over the base length v_m = dx/dt assigned to the mid-point of the measuring base.
SIMULATION	General description		Duration simulator with amplifier 84.
ESTIMATED ACCURACY	Velocity		Relative uncertainty regarding calculated speed: 0.1 % (at 2 s). Validation possible by analysis of analogue signals on oscilloscope.
ERROR INDICATION	General description		-
APPLICATIONS FIELD OF USE	General description		Firing range or outside Horizontal or low-angle (< 20°) fire
	Calibre range		5 mm to 155 mm
	Velocity range		50 m/s to 2000 m/s
	Elevation range		Horizontal or low-angle (< 20 °) fire Individual shots or bursts.
	Adjustable trajectories of measurements		-
	Temperature Range	Sky screens	-10 °C to + 50 °C
		Velocity meter	-
	Rate-of-Fire		-
	Projectile types		Any types with or without tracer.
SPECIALS			System with two independent channels allowing double measurements. Preamplifier incorporated; pass-band 20 Hz-400 kHz.
RESTRICTIONS			-
INCOMPATIBLE	with		Sub-calibre munitions (projectiles launched by sabots). Unfavourable atmospheric conditions (heavy rain, mist).
Table ends			

SYSTEM SPECIFICATION SHEET	No.: A-19
	-

SYSTEM used by	FRA

Function	Specifications	
DETECTOR	System	Infrared optical barriers BOMET
	Type of detector	-
	Name	-
	Manufacturer (Country of Origin)	ETBS, FRA
	Transmitter frequency	-
	Transmitter power	-
	Antenna gain	-
	Warming up	-
	Base length (and tolerance)	-
OPERATION	General description	A luminous plane generated by an incandescent source (linear-coiled lamp) is partially occulted by the passage of the projectile. A system of photodiodes detects the variation in the luminous flux and supplies an analogue signal, image of the projectile profile. Two identical barriers are used to measure the velocity.
AMPLIFIERS	General description	Generates calibrated pulses by thresholding the analogue signal.
	AMPLI 84	4 independent channels. Adjustable gain (3 positions). Pass-band 30 Hz - 200 kHz. Triggering threshold continuously adjustable. Detection of cap, base or tracer. Incorporated duration simulator.

Table continues

SYSTEM SPECIFICATION SHEET	No.: A-19
	continued

Function	Specifications	
CHRONOMETERS	Description	Triggered by the pulses supplied by the amplifier.
	CALVI 73 (measurement of individual shots)	1 channel. Time base 1 MHz and 10 MHz. Base length adjustable by thumbwheels. Stop and automatic reset functions incorporated. Output: time and velocity (5-digit LED display), BCD output.
	CALVI 90 (measurement of shots and bursts)	1 channel. Time base 10 MHz. Base length programmable. Stop and automatic reset functions incorporated. Capacity: 8000 shots. Incorporated programming key-board. Outputs: time and velocity (4x20-character plasma display), HP-IB bus.
	CHROCAL (shots and bursts)	4 independent channels. Time base 10 MHz. Programmable base length. Stop and automatic reset functions incorporated. Capacity: 500 shots. Remote programming keyboard. Outputs: number of shots (3-digit LED display), time and velocity (printer), HP-IB bus.
COUNTERS	Name	-
	Time base resolution	-
	Measuring base resolution	-
	Read out	-
	Number of counters	-
	Independence of counters	-
	Precision	-
	Crystal stability	-
	Crystal in temperature control oven	-
	Display	-

Table continues

SYSTEM SPECIFICATION SHEET	No.: A-19
	continued

FUNCTION	Specifications		
OUTPUT	General description		-
	Display		-
METHOD OF CALCULATION OF THE VELOCITY	General description of the method used for the calculation of the velocity of a projectile at a specific point (e.g. initial velocity).		Average velocity over the base length v_m = dx/dt assigned to the mid-point of the measuring base.
SIMULATION	General Description		Duration simulator with amplifier 84.
ESTIMATED ACCURACY	Velocity		Relative uncertainty regarding. Calculated speed: 0.1 % (at 2 s). Validation possible by analysis of analogue signals on oscilloscope.
	Probable errors		-
ERROR INDICATION	General description		-
APPLICATIONS FIELD OF USE	General description		Firing range or outside, horizontal fire
	Calibre range		5 mm to 155 mm
	Velocity range		50 m/s to 2000 m/s
	Elevation range		-
	Adjustable trajectories of measurements		-
	Temperature range	Sky screens	-
		Velocity meter	-
	Rate-of-Fire		Individual shots or bursts
	Projectile types		Any type with or without tracer
SPECIALS	-		System with two independent channels allowing double measurements. Preamplifier incorporated: pass-band 600 Hz - 450 kHz.
RESTRICTIONS	-		-
INCOMPATIBLE	with		Sub-calibre munitions (projectiles launched by sabots). Unfavourable atmospheric conditions (heavy rain, mist).
Table ends			

SYSTEM SPECIFICATION SHEET	No.: A-20
	-

SYSTEM used by	FRA

Function	Specifications	
DETECTOR	System	Artillery velocity meter RDB-4.
	Type of detector	-
	Name	-
	Manufacturer (Country of Origin)	IN-SNEC (Intertechnique group), FRA
	Transmitter frequency	Transmission frequency F: 5 frequencies can be selected from F_1 (10388 MHz) to F_5 (10391 MHz) in steps of 750 kHz.
	Transmitter power	Radiated power: 400 mW
	Antenna gain / lobe	Gain in the axis: 24 dB / 9° x 14° (at -3 db)
	Polarisation	Rectilinear H or V depending on orientation
	Warming up	-
	Operating temperature	-37 °C to + 60 °C
	Base length (and tolerance)	-
	Particular features	Single-antenna radar. Microphone for triggering from muzzle voice incorporated. Accelerometer incorporated to correct for recoil speed.
OPERATION	General description	Microwaves transmitted towards the projectile are partially reflected by it. On return their frequency has been slightly modified by the Doppler effect due to the radial velocity of the projectile. A processing system extracts this frequency shift (proportional to the perceived radial velocity) from the carrier frequency.
AMPLIFIERS	General description	Works in frequency mode (searching for Doppler line in frequency spectrum obtained by FFT processing). - Band pass filter 3.5 kHz - 140 kHz

Table continues

SYSTEM SPECIFICATION SHEET	No.: A-20
	continued

Function	Specifications	
AMPLIFIERS COUNTINUED		- Sampling frequency f_s: 200 kHz (v < 1300m/s) and 333 kHz (v > 1300 m/s) - Digital / analogue conversion: 12 bits - Number of FFT points N: 1024 - Number of measurements: 6 to 40 depending on ballistics of projectile.
CHRONOMETERS	Description	-
COUNTERS	Name	-
	Time base resolution	-
	Measuring base resolution	-
	Read out	-
	Number of counters	-
	Independence of counters	-
	Precision	-
	Crystal stability	-
	Crystal in temperature control oven	-
	Display	-
OUTPUT	General description	-
	Display	-
METHOD OF CALCULATION OF THE VELOCITY	General description of the method used for the calculation of the velocity of a projectile at a specific point (e.g. initial velocity).	The initial velocity is calculated by a first order regression when the period of measurement is less than 300 ms and by a first or second order regression in other cases.
	Display of v_0	The initial velocity v_o. The initial velocities of the last 999 shots. The average velocities of the last 999 bursts. The initial velocity of each shot of the last burst.

Table continues

SYSTEM SPECIFICATION SHEET	No.: A-20
	continued

Function	Specifications		
SIMULATION	General description		Velocity simulator incorporated (v = 965.45 m/s for frequency F_1) by microwave diode 66.91 kHz.
ESTIMATED ACCURACY	Velocity		Resolution: 0.1 m/s Accuracy: 0.1 % for v_o > 1000 m/s and ± 1 m/s for v_o < 1000 m/s.
ERROR INDICATION	General description		-
APPLICATIONS FIELD OF USE	Calibre range		30 mm to 200 mm
	Velocity range		50 m/s to 2000 m/s
	Elevation range		-
	Adjustable trajectories of measurements		-
	Temperature range	Sky screens	-
		Velocity meter	-
	Rate-of-Fire		Individual shots or bursts (rate < 1200 shots/min).
	Projectile types		All, including tracer and base-bleed.
SPECIALS	-		-
RESTRICTIONS	-		-
INCOMPATIBLE	with		Fragmenting munitions. Metallic obstacles in a sector of radius 200 m within ± 15° from the firing axis.
Table ends			

Part III

LIST OF NEW VELOCITY MEASUREMENT SYSTEMS NOT YET APPROVED BY NATO

AEP- 34

PART III

INDEX

LIST OF VELOCITY MEASUREMENT SYSTEMS NOT YET APPROVED BY NATO[1)] TO BE USED IN THE PRODUCTION AND TESTING OF NATO STANDARDIZED GUNS AND AMMUNITION

NATION: ITALY					
MEASUREMENT SYSTEM (COUNTRY OF ORIGIN)	**TYPE**	**APPLICATION**			**SYSTEM SPECIFI-CATION SHEET No.**
		Calibre - Small (S) - Medium (M) - Large (L)	**Use** - Field (F) - Proving Ground (PG)	**Elevation** - Horizontal (H) - Angle (A)	
MAGNETIC COILS AVL (AUT)	EV210 + B212BC	M	PG	H	B-1

1) alternatively by ISO 9001

PART IV

SYSTEM SPECIFICATION SHEETS

OF OTHER VELOCITY MEASUREMENT DEVICES

SYSTEMS NOT YET APPROVED BY NATO

AEP- 34

PART IV

SYSTEM SPECIFICATION SHEETS OF NEW VELOCTIY MEASUREMENT SYSTEMS NOT YET APPROVED BY NATO

Sheet No.	System Name	User Nation
B-1 IV-3	EV210 Magnetic Coil Screen System	ITA

SYSTEM SPECIFICATION SHEET	No.: B - 1
	-

SYSTEM used by	ITA

Function	Specifications	
DETECTOR	System	Electric magnetic
	Type of detector	Self-exciting coil screen system
	Name	EV 210 self-exciting system
	Manufacturer (Country of Origin)	AVL Ballistic Division (Austria)
	Transmitter frequency	-
	Transmitter power	-
	Antenna gain	-
	Warming up	-
	Base length (and tolerance)	2000 mm ± 1 mm
OPERATION	General description	-
AMPLIFIERS	General description	2 one-channel input amplifiers providing a choice of 2, 5, 10 times amplification
CHRONOMETERS	Description	-
COUNTERS	Name	Transient and time recorder B212 BC
	Time base resolution	0.1 ms
	Measuring base resolution	-
	Read out	Digital readout
	Number of counters	2
	Independency of counters	yes
	Precision	1 count = 10^{-7} sec
	Crystal stability	± 25 ppm
	Crystal in temperature control oven	
	Display	Digital readout
OUTPUT	General description	2 values of velocity corresponding to the two couples of coils, mean value, min value, range (max – min)
	Display	

Table continues

SYSTEM SPECIFICATION SHEET	No.: B - 1
	continued

Function	Specifications		
METHOD OF CALCULATION OF THE VELOCITY	General description of the method used for the calculation of the velocity of a projectile at a specific point (e.g. initial velocity)		The observed velocities are calculated from the individual channel times and corresponding coil screen base lengths. These are then averaged to give the reported OV. Rejection is based on a total spread in velocities of not greater then 0.1 % of the average OV.
SIMULATION	General description		External signal generator
ESTIMATED ACCURACY	Velocity		Velocity is accurate to 0.2 %.
ERROR INDICATION	General description		-
APPLICATIONS FIELD OF USE	Calibre range		6.5 mm to 20 mm with 25 cm dia coils 6.5 mm to 40 mm with 40 cm dia coils
	Velocity range		50 m/s - 2500 m/s
	Elevation range		-10° to +10°
	Adjustable trajectories of measurements		-
	Temperature range	Sky screens	0 °C to +40 °C
		Velocity meter	-
	Rate-of-Fire		Maximum shot number in a burst: 150 Maximum 2500 burst/min Minimum 24 burst/min
	Projectile types		-
SPECIALS	-		-
RESTRICTIONS	The equipment can not used with		Ammunition that do not include any form of ferruginous material.
INCOMPATIBLE	with		-
Table ends			

PART V

INCLUSION OF NEW EQUIPMENT IN LIST A

AEP- 34

1. GENERAL

1.1 Acceptance of National Velocity Measurement Systems will be based only on the results of comparison firings in which the National System submitted for inclusion (National Velocimeter) is compared with two NATO approved velocity measurement systems (Standard Velocimeter) each having at least one single channel.

1.2 The country submitting the national equipment for inclusion (country of origin) shall determine which Standard Velocimeter shall be used in the comparison firings.

1.3 Approval of a National Velocimeter will normally cover all calibers, all velocities, all elevations and all types of projectiles mentioned bellow:

(a) calibre: - small (< 20 mm)
- medium (≥ 20mm and ≤ 50mm)
- large (> 50 mm).

(b) velocity: - subsonic
- transonic
- supersonic.

(c) elevation: - horizontal firing
- angle firing.

(d) special cases: - discarding sabot
- tracer/base-burn - hollow-base - finned
- hollow base shell with transient yawing motion
- max. charge with tracer/base-burn.

If a National Velocimeter is not able to cover all calibres, all velocities, all elevations and all types of projectiles a remark has been done in the approved and specification list (Part I and Part II).

Although contractor test results should be taken into consideration at least some firings under the most extreme configurations should be conducted. The extreme configurations should be a function of potential weakness in the new equipment specifications and/or contractor supplied test results. Extreme means, for example, small radar cross-section, shock and blast environment, very low or rapidly changing velocities, side-lobe interference, ionization).

For the purposes of this AEP, horizontal firing will be considered to be between approximately, -50 and +50 mils and angle firing, greater than approximately 200 mils. Approval shall be granted for each configuration where satisfactory performance is achieved. If angle firing is not a significant factor for the equipment being tested, firings need only be conducted for horizontal firing.

1.4 The performance criteria for inclusion of a National Velocimeter as a NATO approved system shall be no more or less stringent than those of the Standard

Velocimeter against which it is being compared.

1.5 Each velocimeter shall be set up and used in accordance with the standard procedure pertaining to that velocimeter as outlined in Part II and Part IV.

1.6 Velocimeter sensors shall be set up in sufficiently close proximity to each other to enable them to observe essentially the same velocity level but not so close as to cause interference between instruments.

2. TEST REQUIREMENTS

2.1 For at least two extreme configurations, agreed to by the country of origin and the country conducting the test, shall be used. If the country of origin and the country conducting the test are the same, agreement with some other NATO countries (chosen by the country of origin) shall be required.

The approval of any configuration through the appropriate group of experts in the NATO structure (AC/225 LG/4 SG/2) shall be acquired prior to the conduct of the test.

2.2 Prior to firing the first reference round, the country of origin and the country conditioning the test shall agree on the number of rounds required to be fired from each weapon.

2.3. For every **configuration** (elevation/velocity etc.) fired, a minimum sample size of 20 rounds measured by all three velocimeters must be used in the data analysis after removing the following data from consideration:

(a) Data from pre-test rounds.

(b) Rounds where data omission occur for one or more velocimeter. A maximum of two data omissions per velocimeter is permitted.

(c) Rounds where data for one or more velocimeter is considered to be extreme. This occurs if the difference between one data and the mean value of all the three measured data in one round is greater than 0.5 % of the calculated mean value. The number of extreme values of the National Velocimeter being deleted can not exceed that of the Standard Velocimeter. A maximum of two data omissions per velocimeter is permitted.

(d) Data means either the calculated muzzle velocity or the velocity determined at a certain distance from the muzzle.

3. ACCEPTANCE CRITERIA

3.1 The following procedures (Paragraphs 3.2 - 3.6) shall be followed for each configuration for which NATO approval is desired.

3.2 All tests for significance (t-tests) shall be made at the 95 per cent level of confidence.

3.3 Estimates of variance in errors of precision shall be computed for each velocimeter (see Part VI, Paragraph 2).

3.4 The two Standard Velocimeters must be performing with satisfactory precision and accuracy to qualify the firing as a "valid" test. The test shall be declared "valid" when the Standard Velocimeters are found to have satisfactory precision of measurement (Part VI, Paragraph 2.1) and satisfactory agreement in average velocity readings (Part VI, Paragraph 2.2). The test shall be declared "invalid" when the Standard Velocimeters are found to have unsatisfactory precision of measurement. In the case where the Standard Velocimeters have satisfactory precision of measurement but unsatisfactory agreement in average velocity readings (bias), a reason for the bias should be sought. If a systematic error can be detected and explained the results may be corrected and the analysis repeated beginning at Paragraph 3.3 above.

3.5 Once a "valid" test has been conducted, final approval of the National Velocimeter shall be determined on the basis of its performance relative to the average performance of the two Standard Velocimeters gathering the same data. Tests for precision and bias (similar to those just applied to determine a "valid" test) are performed, this time comparing the average Standard Velocimeter velocity readings with the National Velocimeter velocity readings. The National velocimeter shall have acceptable precision and accuracy when it is found to have satisfactory precision of measurement (Part VI, Paragraph 3.1) and satisfactory agreement in average velocity readings (Part VI, Paragraph 3.2). The National Velocimeter shall be declared unacceptable when it is found to have unsatisfactory precision of measurement. In the case where the National Velocimeter has satisfactory precision of measurement but unsatisfactory agreement in average velocity readings (bias), a reason for the bias should be sought. If a systematic error can be detected and explained, the results may be corrected and the analysis repeated beginning at Paragraph 3.3 above.

3.6 A report containing the complete data analysis shall be submitted to the appropriate group of experts in the NATO structure. NATO approval shall be granted for one or more configurations (Paragraph 1.3) if the National Velocimeter meets the criteria for precision and bias specified in Part VI.

PART VI

STATISTICAL METHODS

AEP- 34

1. INTRODUCTION

1.1 DEFINITIONS

All velocimeter observations consist of the sum of three components: the true velocity, instrumental bias error and random error of measurement.

a_i = i^{th} observation from the first Standard Velocimeter
($a_i = X_i + \beta_1 + e_{i1}$)

b_i = i^{th} observation from the second Standard Velocimeter
($b_i = X_i + \beta_2 + e_{i2}$)

c_i = i^{th} observation from the National Velocimeter
($c_i = X_i + \beta_3 + e_{i3}$)

X_i = True velocity of the i^{th} round

β_i = Instrumental bias error of the j^{th} velocimeter

e_{ij} = Random error of measurement of the i^{th} round by the j^{th} velocimeter. It is assumed that e_{ij} is normally distributed with mean of zero and variance $\sigma^2 e_j$, when
$j = 1 \quad \sigma^2 e_j = \sigma^2 e_a$
$j = 2 \quad \sigma^2 e_j = \sigma^2 e_b$
$j = 3 \quad \sigma^2 e_j = \sigma^2 e_c$
[$\beta_j + e_{ij}$ = total error measurement of the ith round by the jth velocimeter]

n = Sample size (See Part V, Paragraph 2.3)

t_o = Computed t value of the observed data

t = Significance values from the *Student-t* table

1.2 ESTIMATION OF VARIANCES IN ERRORS OF MEASUREMENT (PRECISION ERRORS)

$$\text{est}(\sigma^2 e_a) = S^2_a - S_{ab} - S_{ac} + S_{bc}$$
$$\text{est}(\sigma^2 e_b) = S^2_b - S_{ab} + S_{ac} - S_{bc}$$
$$\text{est}(\sigma^2 e_c) = S^2_c + S_{ab} - S_{ac} - S_{bc}$$

where $S^2_a = \dfrac{1}{n-1}\sum_{i=1}^{n}(a_i - \bar{a})^2$ with $\bar{a} = \frac{1}{n}\sum_{i=1}^{n} a_i$

and

$$S_{ab} = \frac{n\sum_{i=1}^{n} a_i b_i - \left(\sum_{i=1}^{n} a_i\right)\left(\sum_{i=1}^{n} b_i\right)}{n(n-1)}$$

Negative estimates of variance in errors of measurement shall be taken as equal to zero.

2. REQUIREMENTS FOR "VALID" TEST

2.1 COMPARISON OF THE PRECISIONS OF THE TWO STANDARD VELOCIMETERS

(a) Definitions:

$H_o : \sigma^2 e_a = \sigma^2 e_b$

$$t_0 = \frac{r(yz)\sqrt{n-2}}{\sqrt{1-r^2(yz)}}$$

where:

$y_i = a_i + b_i$

$z_i = a_i + b_i$

$$r(yz) = \frac{S(yz)}{\sqrt{S^2(y)\,S^2(z)}}$$

H_o is acceptable when $t_{2.5}(n - 2) \leq t_{97.5}(n - 2)$ where $t_{2.5}(n-2)$= 0.025 percentile of the t distribution with (n - 2) degrees of freedom and $t_{97.5}(n - 2)$ = 0.975 percentile of the t distribution with (n - 2) degrees of freedom.

(b) The precisions of the Standard Velocimeter are acceptable if:

Either

est(se_a) and est(se_b) ≤ 0.20 m / se or

est(se_a) and est(se_b) ≤ 0.05% $\frac{(\bar{a} + \bar{b})}{2}$

However, when the results of these comparison firings are presented to the appropriate group of experts in the NATO structure for NATO approval, the acceptance or rejection of H_o will be included in that presentation.

(c) It has been found, from experience, that on some occasions, est(σ_e) can exceed 0.05% $\frac{(\bar{a} + \bar{b})}{2}$ but valid reasons can be found for these high estimates.

Therefore, if est(σ_e) > 0.05% $\frac{\left(\bar{a}+\bar{b}\right)}{2}$ but ≤ 0.10% $\frac{\left(\bar{a}+\bar{b}\right)}{2}$, and valid reasons can be found for these high estimates, this information can be given to the appropriate group of experts in the NATO structure for a judgement of acceptability. In this case, the acceptance or rejection of H_o will play an important role in the decision taken by the NATO group of experts.

(d) If est(σe_a) or est(σe_b) does not meet the criteria given in either (b) or above, the precisions of the Standard Velocimeters shall be declared unsatisfactory.

2.2 COMPARISON OF THE AVERAGE VELOCITY READINGS FROM THE TWO STANDARD VELOCIMETERS

(a) Definitions:

$H_o : \beta_a = \beta_b$

$$t_o = \frac{\bar{z}\sqrt{n}}{S(z)}$$

where

$z_i = a_i - b_i$

H_o acceptable when: $t_{2.5}(n-1) \leq t_o \leq t_{97.5}(n-l)$

where $t_{2.5}(n-1)$ = 0.025 percentile of the t distribution with (n-1) degrees of freedom and $t_{97.5}(n-1)$ = 0.975 percentile of the t distribution with (n-1) degrees of freedom.

(b) The average velocity readings of the two Standard Velocimeters are acceptable if:

Either H_o is accepted or $\left|\bar{a}-\bar{b}\right| \leq 0.10\% \frac{\left(\bar{a}-\bar{b}\right)}{2}$.

(c) It has been found, from experience, that even if the above criterion is not met, on many occasions a calibration error can be detected. In that case, the results may be corrected and the analysis repeated. (See Part V, Paragraph 3.4).

(d) If the average velocity readings do not meet the criterion given in Paragraph (b) above or can not be calibrated as stated in Paragraph (c) above, the agreement between the average velocity readings shall be declared unsatisfactory.

3. REQUIREMENTS FOR FINAL APPROVAL OF THE NATIONAL VELOCIMETER

3.1 COMPARISON OF THE PRECISION OF THE NATIONAL VELOCIMETER WITH THE AVERAGE PRECISON OF THE TWO STANDARD VELOCIMETERS

(a) Definitions

$$H_o: \sigma^2 e_c \leq \frac{\sigma^2 e_a + \sigma^2 e_b}{2}$$

$$t_0 = \frac{\left(\frac{S^2(u)}{S^2(v)} - 0{,}75\right)\sqrt{n-2}}{\sqrt{3\left(1 - r^2(uv)\right)\left(\frac{S^2(u)}{S^2(v)}\right)}}$$

where

$$u_i = c_i - \frac{(a_i - b_i)}{2} \quad \text{and} \quad v_i = a_i - b_i$$

H_o acceptable when $t_o \leq t_{95}(n-2)$ where $t_{95}(n-2)$ = 0.95 percentile of the t distribution with (n-2) degrees of freedom.

(b) The precision of the National Velocimeter is acceptable if:

Either H_o is accepted,

or $\text{est}(\sigma e_c) \leq 0.20$ m / sec,

or $$\text{est}(\sigma e_c) \leq 0{,}05\% \frac{\left(\bar{a} + \bar{b}\right)}{2}$$

(c) It has been found, from experience, that on some occasions, $\text{est}(\sigma e_c)$ can exceed $0{,}05\% \frac{\left(\bar{a} + \bar{b}\right)}{2}$ but valid reasons can be found for such a high estimate. Therefore, if $\text{est}(\sigma e_c) > 0{,}05\% \frac{\left(\bar{a} + \bar{b}\right)}{2}$ but $\leq 0{,}10\% \frac{\left(\bar{a} + \bar{b}\right)}{2}$ and valid reasons can be found for this high estimate, this information can be given to the appropriate group of experts in the NATO structure for a judgment of acceptability.

(d) If $\text{est}(\sigma e_c)$ does not meet the criteria given in either (b) or (c) above, the precision of the National Velocimeter shall be declared unsatisfactory.

3.2 COMPARISON OF THE AVERAGE VELOCITY READING FROM THE NATIONAL VELOCIMETER WITH THE AVERAGE OF THE TWO STANDARD VELOCIMETERS

(a) Definitions

$$H_o: \beta_c = \frac{\beta_a + \beta_b}{2}$$

$$t_o = \frac{\bar{u}\sqrt{n}}{S(u)} \qquad \text{where } u_i = c_i - \frac{(a_i + b_i)}{2}$$

H_o acceptable when $t_{2.5}(n-1) \le t_0 \le t_{97.5}(n-1)$

where $t_{2.5}(n-1) = 0.025$ percentile of the t distribution with (n-1) degrees of freedom and $t_{97.5}(n-1) = 0.975$ percentile of the *t distribution* with (n - 1) degrees of freedom.

(b) The average velocity reading of the National Velocimeter is acceptable if:

Either H_o is accepted or:

$$\left| \bar{c} - \frac{(\bar{a} + \bar{b})}{2} \right| \le 0.10\% \frac{(\bar{a} + \bar{b})}{2}$$

(c) It has been found, from experience, that even if the above criterion is not met, on many occasions a calibration error for the National Velocimeter can be detected. In that case, the results may be corrected and the analysis repeated. (See Part V, Paragraph 3.5).

(d) If the average velocity reading of the National Velocimeter does not meet the criterion given in Paragraph (b) above or can not be calibrated as stated in Paragraph (c) above, this average velocity reading shall be declared unsatisfactory.

4. REFERENCES

(a) Engineering Design Handbook, DARCOM-P 706-103, December 1983, Dept. of the Army.

(b) Frank E. Grubbs, "Errors of Measurement, Precision, Accuracy and the Statistical Comparison of Measuring Instruments", Technometrics 15, 53-66 (February 1973).