Review of fragment simulating projectiles definition and associated quality controls needed

F.Barbillon[1], P.Martin[1], P.Mabire[1] and F.Mouhot[2]

[1]DGA Land Systems, Rocade Est, Echangeur de guerry, 18021 Bourges Cedex, France
franck.barbillon@intradef.gouv.fr
[2]DGA Aeronautical Systems, 47 Rue Saint-Jean, 31130 Balma, France

Abstract. STANAG 2920 is a NATO standardization agreement which deals with classification of level of ballistic protection of personal protective equipment. Its associated Allied Engineering Publication (AEP 2920) describes the procedure for classification of personal armour for protection against bullets and fragment threat. The ballistic tests shall be carried out using selected threat ammunition or fragment simulators defined in AEP 2920. Inconsistencies were found in the definition of fragment which can implies misunderstanding for fragment manufacturers, suppliers and test houses. Using inconsistent fragment for assessing level of protection can result in wrong decision in acceptance or qualification process. Analyses of different definition available were conducted and new drawings were built (FSP without skirt, FSP with skirt and RCC). Sizes, tolerances and masses were adjusted to be in compliance with reference standards like MIL-DTL-46593, UK drawings and so-on. Some requirement were added like burrs sizes tolerances. Moreover, STANAG 2920 suggests that the test facility shall take a representative sample from each batch and check the hardness, dimensions and weight. But, guidelines must be given regarding sampling to achieve confidence in new batches. Rockwell hardness measurement is not consistent for small fragments uses for personal protection equipment and hardness measurement methods are inaccurate and must be conducted in respect with available standards like ISO standard. Different results obtained during fragment procurement processes are highlighted and new drawings and requirement proposed for the next STANAG 2920 will be explained and shared with attendees.

1. CURRENT STANAG 2920 FRAGMENTS DEFINITION

Last NATO standardization agreement STANAG 2920 [1] is associated with Allied Engineering Publication AEP 2920 [2]. The purpose of these documents is to establish a standard classification to designate the protection level of Personal Armour (hard armour, soft armour, helmets, face and eye protection) against bullets and fragmentation threat when exchanging tactical information in NATO or to ensure interoperability in multinational missions. Participating nations or test houses agree to use the method of classification described in the standard and to classify on the basis of ballistic tests performed according to the standard. Therefore, fragment-simulating projectiles (FSP[1]) shall meet the specifications detailed in AEP 2920 [2]. Bolduc et al. described [3] which type of fragment are included (or removed) in current edition of STANAG 2920 [1][2]. Three types are defined:

- Chisel nose cylinders launched with sabot (designated by letter "F") or FSP without skirt,
- Chisel nose cylinders launched without a sabot (designated by letter "G") or FSP with skirt,
- Right Circular Cylinders (RCC) (designated by letter "R").

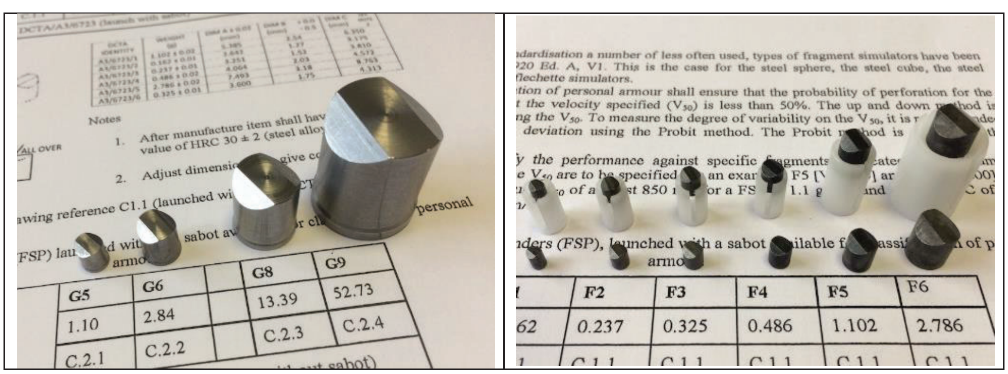

Figure 1. Pictures of fragments defined in current AEP 2920 [2] [4]
- Left: "G" fragments with skirt- Right: "F" fragments without skirt

[1] a projectile of a specific material, shape and size for ballistic test firings so that the effect of typical munition fragments can be simulated

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Conducting testing in compliance with AEP 2920 imply (see. § 5.5.2.c in [2]):

- "*….the fragment simulator used to simulate the fragment threat shall conform to the drawings and tables provided in annex…,*
- *Fragment simulators shall be certified by vendors to meet the specifications in annex,*
- *Before use, the test facility shall take a representative sample from each batch and check the hardness (measured on the side), dimensions and weight*…"

Despite these fragment definitions in AEP 2920 [2] perceived as being relevant and rigorous, procurement agencies and test houses were registering irregular results from their testing. It is clear that fragment is only one of few factors of irregular result but variability in ballistic impact performance could be explain by projectile physical properties and dimensions [5]. Nevertheless, using inconsistent fragment for assessing level of protection can result in wrong decision in acceptance or qualification process. Moreover, test houses who are ISO 17025 [6] certified or in an ISO 17025 certification process shall prove they are using fragments which are in compliance with our NATO Standard.
Based on capitalized feedbacks, STANAG 2920 team of experts decided to improve fragment definition and resolve inconsistencies found which can implies misunderstanding for fragment manufacturers, suppliers and test houses. Moreover, next AEP must tightening up some requirements and include guidelines for quality controls and hardness measurement.

The purpose of this article is to share analysis and inconsistencies of different existing FSP definitions and share corrected or selected values for next AEP 2920 (expected in 2021). First paragraphs explain reviewing of weight and dimensions for FSP with or without skirt and associated achievability. In a second part, are highlighted requirements for material to be used for manufacturing fragment, hardness, burrs removal and surface finish. A third part deals with huge difficulties in quality controls mainly regarding hardness. To conclude, this article presents the three new drawings proposed for next AEP 2920 (FSP without skirt, FSP with skirt and RCC).

2. REVIEWING DEFINITION OF FSP WITHOUT SKIRT

The six smallest FSPs without skirt are described in STANAG 2920 edition 1 since 1996 [7] and are based on UK Drawing DCTA/A3/6723 build in the 80's. In the current AEP 2920 [2], they are called F1 to F6; the number defining the weight of the fragment simulating projectile. More recently, FSPs for saboted launch were introduced in MIL-DTL-46593B in 2006 [8,9]. This detail specification also describes a 5.56 mm and 7.62 mm caliber FSPs as in UK Drawing and defines 12.7 mm caliber and 20 mm caliber FSPs without skirt. Therefore, in the way to be comprehensive, these four FSPs coming from MIL-DTL-46593B were included in the AEP 2920 [2]. Table 1 below resume available definitions of FSPs without skirt. Unfortunately, it means existing two definitions of 5.56 mm and 7.62 mm caliber FSPs (called F5 and F6) in AEP 2920. This type of fragment could be launched with both smooth and rifled barrel. For rifled barrel, sabot is used. FSP fragment F5 weight 1.1 g is often called the 17gr FSP.

Table 1. Summary of standards describing FSP without skirt (current standard in bold)

<table>
<tr><th>Class [2]</th><th>F1</th><th>F2</th><th>F3</th><th>F4</th><th>F5</th><th>F6</th><th></th><th></th></tr>
<tr><td>Caliber (mm)</td><td></td><td></td><td></td><td></td><td>5.56</td><td>7.62</td><td>12.7</td><td>20</td></tr>
<tr><td>2920 Ed 1 [7]</td><td colspan="6">UK drawing DCTA/A3/6723</td><td colspan="2">Not defined</td></tr>
<tr><td>2920 Ed 2 [10]</td><td colspan="6">As described in UK drawing DCTA/A3/6723[2]</td><td colspan="2">Not defined</td></tr>
<tr><td rowspan="2">AEP 2920 [2]</td><td colspan="6">UK drawing DCTA/A3/6723[3]</td><td colspan="2"></td></tr>
<tr><td colspan="4"></td><td colspan="4">"FSP for Saboted Launch"
Table C2.1</td></tr>
<tr><td>MIL-DTL-46593B [9]</td><td colspan="4">Not defined</td><td colspan="4">"FSP for Saboted Launch"</td></tr>
</table>

Moreover, the UK drawing in STANAG 2920 is illegible in current AEP 2920 [2]. Regarding this drawing in AEP, method for expressing the dimension values is not in accordance with international rules [11]. In fact, the numerical value and its tolerance should not be given with an excessive number of digits. It usually suffices to quote value and tolerance to at most two significant digits. It also significantly will simplify manufacturer work and quality controls.

[2] UK drawing DCTA/A3/6723 was not included in STANAG 2920 Ed 2

[3] Same reference and issue number as drawing in 2920 edition 1 [7] but with small differences (date, material…)

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2.1 Weight and dimensions correcting

For the smallest fragments F1 to F4, only UK drawing definition exists [2,7,10]. Examples of rewriting UK drawing masses and dimensions in accordance with international rules [11] are given in table 2 for fragment F1 and F2. Same correction are apply to fragment F3 and F4.

Table 2. Corrected weight and dimensions for fragment without skirt F1 and F2

Fragment class	Parameter	Mass	Diameter	Flat size	Length[4]
	Unit	g	mm	mm	mm
F1	Current	0.162± 0.01	2.642± 0.02	$1.27^{0}_{-0,5}$	*3.175*
	Corrected	**0.16± 0.01**	**2.64± 0.02**	$\mathbf{1.27^{0}_{-0,5}}$	***3.17***
F2	Current	0.237± 0.01	3.251± 0.02	$1.52^{0}_{-0,5}$	*3.81*
	Corrected	**0.24± 0.01**	**3.25± 0.02**	$\mathbf{1.52^{0}_{-0,5}}$	***3.81***

For fragment F5 and F6, weight and dimensions must be compare between corrected UK drawing [2] and last MIL-DTL-46593B [9]. Table 3 below gives an overview of weight and dimensions found in standards and proposed values. Table C2.1 in AEP 2920 does not comply with MIL-DTL-46593B [9]. The diameter of F5 fragment is not the same in the two values found in AEP 2920 and seems to come from differences between the UK drawing [2,7,10] and MIL-DTL-46593B [8,9]. For the F6 fragment, differences are found on diameter and flat size. No explanation were found to understand such differences. Corrected value complies with the oldest definition, which come from UK drawing.

Table 3. Selected weight and dimensions for fragment without skirt F5 and F6

Fragment class		Parameter	Mass	Diameter	Flat size	Length[4]
		Unit	g	mm	mm	*mm*
F5	Current	UK drawing [2]	1.102± 0.02	5.385± 0.02	$2.54^{0}_{-0.5}$	*6.35*
		UK drawing corrected	1.10± 0.02	5.39± 0.02	$2.54^{0}_{-0.5}$	*6.35*
		AEP 2920 table C2,1 [2]	1.1± 0.03	5.46± 0.05	2.54± 0.5	*6.35*
		MIL-DTL 46593B[5] [9]	1.10± 0.02	$5.46_{0}^{+0.02}$	$2.54^{0}_{-0.25}$	*6.35*
	Selected		**1.10± 0.02**	**5.39± 0.02**	$\mathbf{2.54^{0}_{-0.5}}$	***6.35***
F6	Current	UK drawing [2]	2.786 ± 0.02	7.493 ± 0.02	$3.18^{0}_{-0.5}$	*8.763*
		UK drawing corrected	2.79 ± 0.02	7.49 ± 0.02	$3.18^{0}_{-0.5}$	*8.76*
		AEP 2920 table C2,1 [2]	2.84 ± 0.03	7.52 ± 0.05	3.45 ± 0.5	*8.64*
		MIL-DTL 46593B[5] [9]	2.85 ± 0.03	$7.52^{0}_{-0.02}$	$3.45^{0}_{-0.25}$	*8.64*
	Selected		**2.79 ± 0.02**	**7.49 ± 0.02**	$\mathbf{3.18^{0}_{-0.5}}$	***8.76***

MIL-DTL-46593B standard [8,9] is considered as reference here for definition of 12.7 mm caliber and 20 mm caliber FSPs without skirt. For convenience with other "Fx" FSPs, they are called respectively F7 and F8. Comparisons with table C2.1 included in last AEP 2920 [2] are in table 4.

Table 4. Selected weight and dimensions for fragment without skirt F7 (12.7 mm) and F8 (20 mm)

Fragment	Parameter	Mass	Diameter	Flat size	Length[4]
	Unit	g	mm	mm	*mm*
F7 (12.7 mm)	AEP 2920 table C2.1 [2]	13.39 ± 0.13	12.57 ± 0.05	5.9± 0.07	*14.73*
	MIL-DTL 46593B[5] [9]	13.41 ± 0.13	12.57 ± 0.03	$5.69^{0}_{-0.38}$	*14.73*
	Selected	**13.41 ± 0.13**	**12.57 ± 0.03**	$\mathbf{5.69^{0}_{-0.38}}$	***15***
F8 (20 mm)	AEP 2920 table C2.1 [2]	53.78 ± 0.26	19.92 ± 0.10	9.27 ± 0.6	*22.86*
	MIL-DTL 46593B[5] [9]	53.78 ± 0.26	$19.91^{0}_{-0.05}$	$9.27^{0}_{-0.3}$	*22.86*
	Selected	**53.78 ± 0.26**	**19.91 ± 0.05**	$\mathbf{9.27^{0}_{-0.3}}$	***23.5***

[4] Length must be adjusted to give correct weight (value with no tolerance)
[5] Weight and dimensions are converted from standard (given in grains and dimensions in inches)

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2.2 Achievability

In order to prove achievability, DGA Land Systems decided to analyse weight and dimensions of 200 fragments randomly chosen in a 2200 batch of "F5" fragments received (quantity based on QL 2 in ISO 6509-2 [13]). All measurement were made in an ISO 17025 certified and independent laboratory [14, 15]. Histograms of diameter, flat size and weight are reported in figure 2. Expanded uncertainty on dimension is U=0.005 mm and U=0.0001g on weight. Results obtained on all dimensions, weight but also on chisel nose angles, symmetry and perpendicularity prove that tolerances in new drawing are clearly achievable by (good) manufacturers.

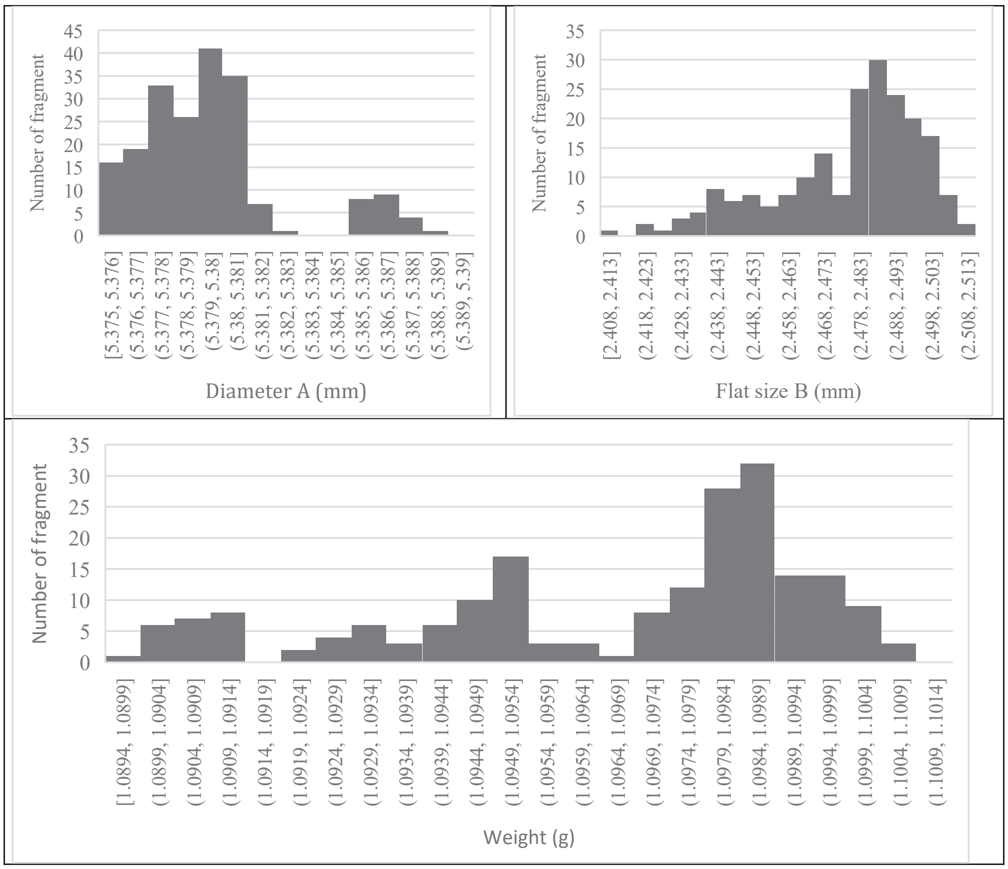

Figure 2. FSP F5 procurement: Histograms of quality control results on 200 fragments

3. REVIEWING DEFINITION OF FSP WITH SKIRT

This type of fragment is launched with rifled barrel. Chisel nose cylinders (FSP) launched without a sabot are designated with character G and an associated number is defining the weight and sizes of the fragment-simulating projectile [2]. Only four fragments exist: caliber 5.56, 7.62, 12.7 and 20 mm. Drawings of FSP with skirt are in MIL-P-46593A [16,17] since 1962 so this standard is assume to be a reference. AEP-55 linked with STANAG 4569 gives a different definition of 20 mm FSP for assessing protection level of armoured vehicles [18]. Table 5 give a summary of values and tolerances given in standards for the 20 mm FSP. Right column gives a proposal for 20 mm FSP weight and sizes based on facts given above. All angle values with their tolerances are similar in all standards analysed and are not reported there. As for FSP without skirt, dimension values are not expressed in accordance with international rules [11]. We can find values and tolerances expressed with a different number of significant digits. Moreover, unit conversion from imperial system to metric system are often wrong[6].

[6] For all analysis here: 1 grain = 0.064799g and 1 inch = 25.4 mm

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Values converted must be rounded to the nearest decimal place but tolerances must be rounded to the lower decimal place. For the "*max flat G*" thickness, value is rounded to the lower decimal place because it is a maximum value. Some differences exist between MIL-DTL- 46593B [9] and MIL-P-46593A [16]: tolerances on the length of skirt are reduced for 20 mm and 7.62 mm FSP (from ± 0.005 to ± 0.002") and external diameter tolerance is reduced for 7.62 mm FSP ($^{+0.003}_{-0.001}$ to ± 0.001). All other fragments are analysed in the same way. For convenience with "Fx" FSPs, 12.7 mm caliber G8 is now called G7 and 20 mm caliber G9 is now called G8. (So, F7 and G7 are caliber 12.7mm, F8 and G8 are caliber 20 mm).

Table 5. Reviewing of weight and sizes of 20 mm FSP (current standard in bold) (cf. § 6.1)

Standard	Mil –P-46593A[16]	2920 Ed 2 [10]	**Mil –DTL-46593B [9]**	**AEP 55 Vol 1 [18]**	**AEP 2920 [2]**	Proposal
Year	1962	2003	2008	2014	2016	
Unit of dimension	*inch*	*mm*	*inch*	*mm*	*mm*	*mm*
Unit of weight	*gr*	*g*	*gr*	*g*	*g*	*g*
Weight	830 ± 4	52.73± 0.26 [7]	830± 4	53.8 ± 0.26	53.78 ± 0.26	53,78 ± 0,25
ØA	$0.784\ ^{0}_{-0.002}$	$19.914\ ^{0}_{-0.05}$	$0.784\ ^{0}_{-0.002}$	19.89 ± 0.05	$19.914\ ^{0}_{-0.05}$	$19.91\ ^{0}_{-0.05}$
ØB	$0.823\ ^{0}_{-0.003}$	$20.904\ ^{0}_{-0.076}$	$0.823\ ^{0}_{-0.003}$	$20.83\ ^{+0.08}_{0}$	$20.904\ ^{0}_{-0.076}$	$20.90\ ^{0}_{-0.07}$
ØC	0.740± 0.005	18.796 ± 0.127	0.740± 0.005	18.80 ± 0.12	18.796 ± 0.127	18.80 ± 0.12
Flat size D	$0.365\ ^{0}_{-0.012}$	$9.27\ ^{0}_{-0.3}$	$0.365\ ^{0}_{-0.012}$	$9.27\ ^{0}_{-0.4}$	$9.27\ ^{0}_{-0.3}$	$9.27\ ^{0}_{-0.30}$
E	$0.912\ ^{+0.010}_{0}$	23.165 ± 0.25	$0.912\ ^{+0.010}_{0}$	24	23.165 ± 0.25	$23.16\ ^{+0.25}_{0}$
F	0.091± 0.005	2.31 ± 0.127	0.091± 0.00**2**	2.31 ± 0.05	2.31 ± 0.127	2,31 ± 0.05
Max flat G	0.008	0.2	0.008	0.2	0.2	0.2
Radius R	$0.910\ ^{0}_{-0.030}$	$23.11\ ^{0}_{-0.75}$	$0.910\ ^{0}_{-0.030}$	**No radius[8]**	$23.11\ ^{0}_{-0.76}$	$23.11\ ^{0}_{-0.76}$
H [9]			0.933	not defined		23.7

4. OTHER REQUIREMENTS

4.1 Materials requirements

Since 1962 and based on MIL-P-46593A[16], material composition for the fragment simulating projectile with skirt shall be "*a cold rolled, annealed steel conforming to compositions 4337 H and 4340H*". In current standard [2,9], these compositions are still requested. These steels are nickel-chromium-molybdenum steels as defined in AISI/SAE[10] designation (43xx family). The H suffix denotes hardenability is a major requirement. Since 2008, these steels are also required for heaviest FSP without skirt F5 to F8 defined in MIL-DTL-46593B [9]. For FSP without skirt F1 to F6, material shall conform to UK drawings requirements. In STANAG 2920 edition 1[7], material is an "*alloy steel to BS 970 PT1 817M40 condition 1*". Unfortunately, material has changed in current AEP 2920 despite the same reference and issue number of UK drawing [2]. Material shall be now "*high carbon bright steel (Silver Steel) to BS 1407*". Chemical compositions for these different steels are shown in table 6. BS970 steel is equivalent to 4340 steel but is not used anymore in standard. Differences in steel, low availability or price of these specific steels encourage manufacturers to find alternative solutions for material, which do not comply with STANAG 2920. For next AEP 2920, uses of 4337H, 4340H or BS1407 will be encouraged but not mandatory. The fragment-simulating projectile could be manufactured from other steels for quenching and tempering that are capable of hardness uniformity within hardness value specified.

Table 6. Chemical composition in weight (%) for different steels used for fragment

Steel	C	Si	Mn	Cr	Ni	Mo
4337H [19]	0.34-0.41	0.20-0.35	0.55-0.90	0.65-0.95	1.55-2.00	0.20-0.30
4340H [20]	0.37-0.44	0.20-0.35	0.55-0.90	0.65-0.95	1.55-2.00	0.20-0.30
BS970 817M40 [21]	0.40	0.25	0.60	1.20	1.55	0.28
BS 1407 [22]	0.95-1.25	0.40 max	0.25-0.45	0.35-0.45		

[7] Weight was by mistake 52.73 g instead of 53.78 g in STANAG 2920 Ed 2 [12] and in AEP 2920 edition A V1 [13]

[8] Shape of 20 mm FSP is different in AEP-55 (flat rear instead of curved rear) despite referencing MIL-P-46593A [16].

[9] The total length of fragment H is not always indicated but manufacturer shall adjust length on base surface to meet indicated weight. Value given for reference only.

[10] American Iron and Steel Institute/Society of Automotive Engineers

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4.2 Hardness requirements

Hardness for FSP without skirt and RCC is always 30±2 HRC (Rockwell hardness C). For FSP with skirt, all current standards agree on the same hardness 30±2 HRC but it was not always the case. Table 7 resumes variability in hardness requirements.

Table 7. Hardness requirements for FSP with skirt in HRC (current standard in bold)

Class	**Year**	**G5**		**G6**	**G7** [11]	**G8** [12]
Caliber (mm)		**5.56 (type 1)**[13]	**5.56 (type 2)**[14]	**7.62**	**12.7**	**20**
MIL-P- 46593 A [16]	1962	*30±1*	*27±3*	*30±1*	*30±1*	*30±1*
2920 Ed 1 [7]	1996	*Refer to US MIL-P-46593A*				
2920 Ed 2 [10]	2003	*30±1*	*27±3*	*30±1*	*30±1*	*30±1*
MIL-DTL- 46593 B [9]	2008	30±2		30±2	30±2	30±2
AEP-55 vol 1 [18]	2014				Refer to MIL-P-46593A But specified 30±2	
AEP 2920 [2]	2016	30±2		30±2	30±2	30±2

4.3 Burrs removal requirements

Burrs are a residue of machining or of a forming process. Deburring process often conducts to have small deviation inside the ideal geometrical shape of an edge. No requirements regarding burrs removal can be found in MIL-P- 46593 A [16] and in MIL-DTL- 46593 B [9]. STANAG 2920 edition 1[7] mentioned that all burrs and sharp edges are to be removed. STANAG 2920 edition 2 [10] and AEP 2920 [2] mentioned that "*all burrs are to be removed and all surfaces are to be as smooth as possible*". No additional information were given and manufacturers are doing that in their own way. It is assume that different burrs removal can change ballistic results especially on soft ballistic panels. It was decided to add requirement for burrs removal. For tolerancing the geometry (sharpness) of edges a standard ISO 13715 has been developed [23]. Symbol for deburr and break sharp edges according ISO standard 13715 could be included now and is therefore, defined on new drawings. Tolerances for burrs removal are $^{-0.05}_{-0.15}$ and are in respect of values met by mechanical design office of DGA Land Systems.

4.4 Finish

For new drawings, the fragment-simulating projectiles shall have a surface roughness value Ra equal to 1.6 micrometres (or roughness ISO grade N7). This value comply with finish required by MIL-DTL-46593B [9] (63 microinches). UK drawings [2, 7] require only 3.2 micrometers.

5. QUALITY CONTROLS

5.1 Sampling requirements

AEP 2920 [2] defines that the test facility shall take a representative sample from each batch and check the hardness (measured on the side), dimensions and weight, before use. Fragment simulators shall be certified by vendors to meet the specifications. However, a representative sample is not defined and what is expected of vendors too. For MIL-P-46593A [16] hardness of all fragment-simulating projectiles defined shall be tested with an acceptable quality level of 2.5 percent defect per hundred with equipment approved by government [16]. Two years later, an amendment was published [17] and substituted the previous "hardness" paragraph with the following one:

- Caliber .22 type 1 (for armor plate), calibres .30, .50 and 20 mm fragment-simulating projectiles shall be one-hundred percent tested for hardness.

MIL –DTL 46593B [9] therefore requires a one-hundred percent quality control for hardness (for fragments F5 to F8 and G5 to G8). Quality control level or sampling must be enough to build confidence to fragments but with an affordable cost. Achievability of parameter during manufacturing process and

[11] Called G8 in current AEP 2920

[12] Called G9 in current AEP 2920

[13] Type 1 for armor plate and type 2 for body armor

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accuracy of measurement means can change the quality control level. Mass and dimensions values are clearly achievable and only few percent controlled can demonstrate compliance with drawings. For hardness, manufacturing process are more complex (machining and heat treatment processes) and inaccuracy in hardness measures is often of the same order than hardness tolerances (see § 5.2). The knowledge and confidence in manufacturer's processes and tools is also very important and can imply quality control level adjustment. Moreover, controls of hardness are destructive testing for small fragments. Nevertheless, certificate of compliance given by vendors or by test houses themselves are not enough and often wrong (very poor sampling, measurement mean not traceable/calibrated to national standard and so on…). These guidelines are proposed to be in the next AEP:

- Test houses shall verify quality of fragment independently from manufacturers/suppliers.
- National Authority[14] shall define level of confidence of quality level. Use ISO2859 [13] for sampling or quality control level choosing is encouraged and 2920 committee will suggest quality control level.
- Hardness, diameters, masses shall be controlled. National authority must define others parameters to be controlled. The use of ISO17025 laboratory for hardness measurement is preferred. Nevertheless, all measurement means used for quality control shall be traceable/calibrated to national standard.

5.2 Quality control of hardness

As define in AEP 2920[2] the fragment-simulating projectile shall be fully quenched and tempered to a Rockwell hardness value as 30±2 HRC. It is proven that (hard) machining can change hardness values and heat treatments are necessary to comply with requirements (See. variability on hardness in figure 3). For small fragment, it is impossible to evaluate the hardness (HRC) because sample is too thin or footprint's penetrator is too large and Vickers measurement methods must be preferred. After measurement conversion from Vickers to Rockwell value must be done and introduce another inaccuracy in results. ISO standards exist to explain hardness measurement (methods, tools, hardness value corrections when testing on cylindrical surfaces, verification and calibration of testing machines and so on…) and how to convert hardness values from different units. Therefore, these guidelines are proposed to be in the next AEP:

- Rockwell hardness measurement shall be done in compliance of ISO 6508 [24],
- Rockwell hardness measures are not always possible and Vickers hardness measures can be used. In this case measurement shall be done in compliance of ISO 6507 [25],
- Conversion from Vickers hardness to Rockwell hardness must be conducted in compliance with ISO 18265 [26] - Small fragments with a mass lower than 2.9 g are to have a Vickers hardness value of HV 295^{+17}_{-18} (based on tables B.2 and C.2 in [26]).
- The position and correction of hardness measurement shall comply with ISO standards (6507 or 6508) [24, 25]. Inaccuracy of hardness measurement shall be evaluate and given within certificate of compliance.

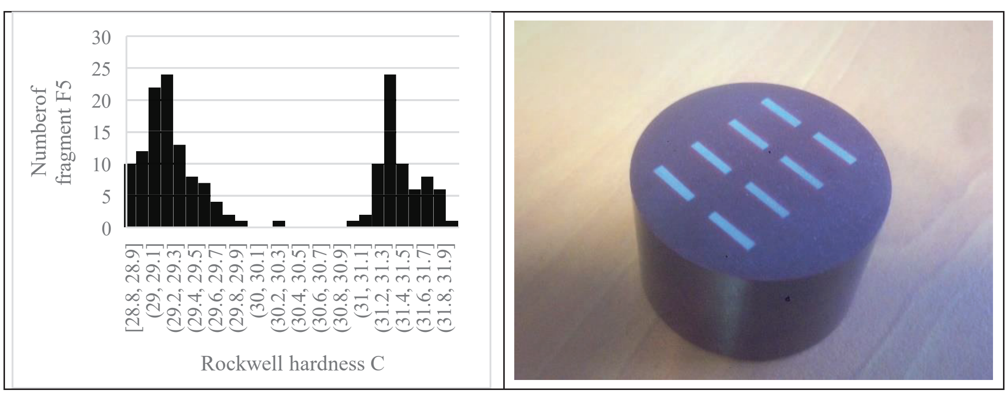

Figure 3. Histogram of hardness quality control on 200 F5 fragments and samples preparation [14,15]

6. NEW DRAWINGS

[14] National Authority (NA): the Authority responsible for the specification of Personal Armour Systems within a Nation or Armed Service [2].

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6.1 Proposed drawings for chisel nose Fragment Simulating Projectile

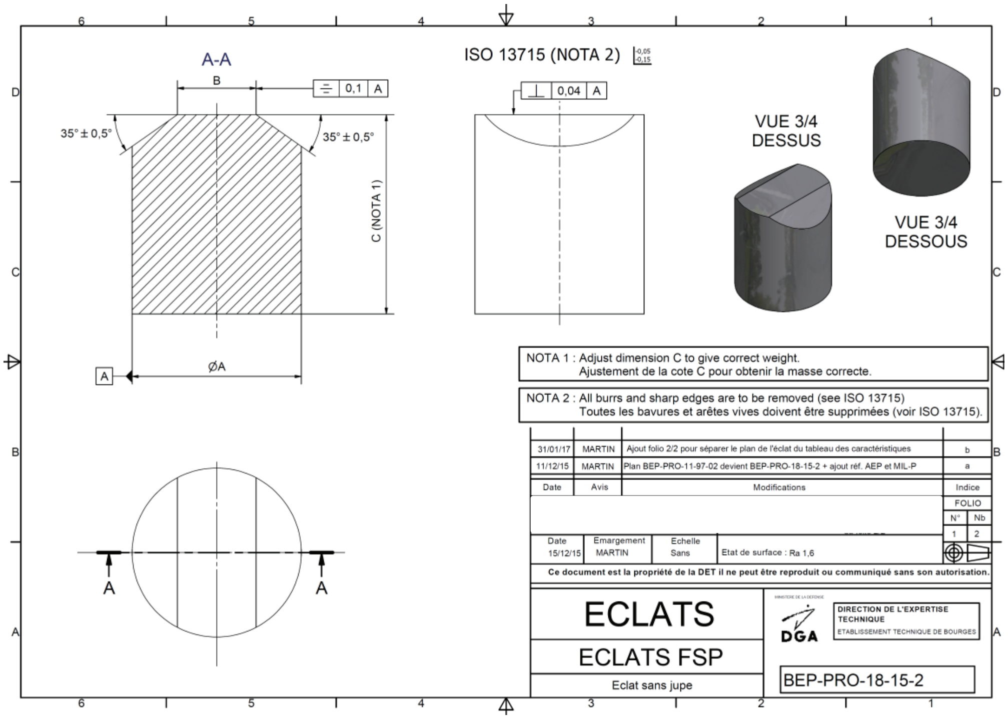

Figure 4. Chisel Nose Fragment Simulating Projectile launched with sabot: F1 (0.16 g) to F8 (20 mm)

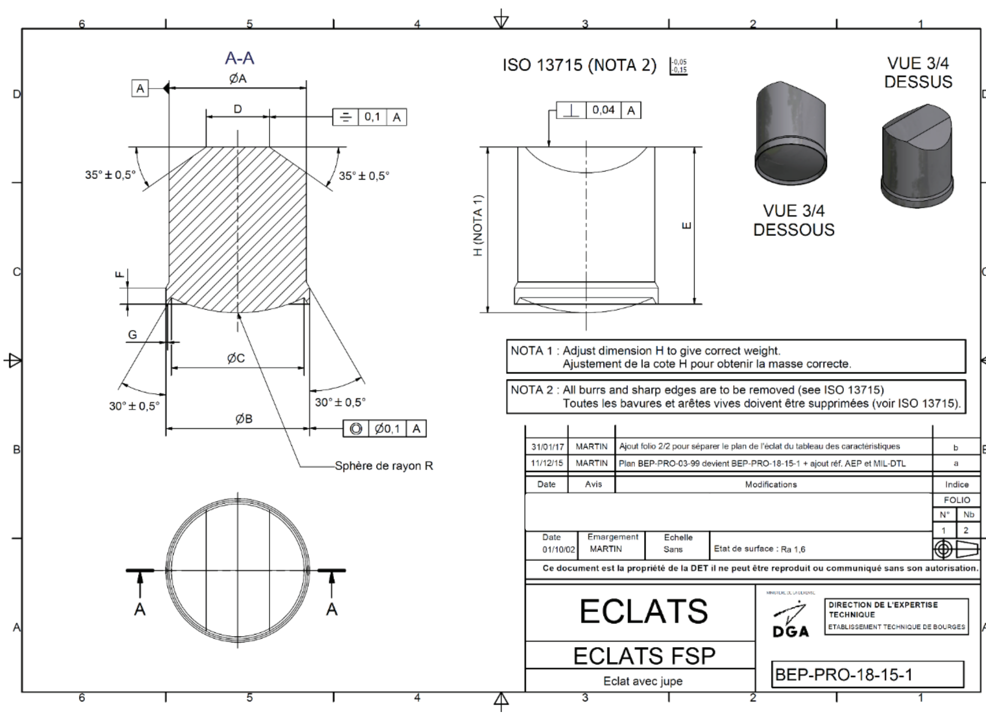

Figure 5. Chisel Nose Fragment Simulating Projectile: G5 (5.56 mm) to G8[15] (20 mm)

6.2 Weight and dimensions for chisel nose Fragment Simulating Projectiles and RCCs

[15] Called G9 in current AEP 2920

Hardness requirement is 30±2 HRC for all fragments (or 295^{+17}_{-18} HV). Tables 8, 9 and 10 give respectively weight and dimensions for FSP without skirt, FSP with skirt and RCCs. Refer to drawing in § 6.1.

Table 8. FSP without skirt characteristics "F"

Class	F1	F2	F3	F4	F5	F6	F7	F8
Mass [g]	0.16 ± 0.01	0.24 ± 0.01	0.33 ± 0.01	0.49 ± 0.02	1.10 ± 0.02	2.79 ± 0.02	13.41 ± 0.13	53.78 ± 0.26
Diameter A (mm)	2.64 ± 0.02	3.25 ± 0.02	3.60 ± 0.02	4.06 ± 0.02	5.39 ± 0.02	7.49 ± 0.02	12.57 ± 0.02	$19.91^{0}_{-0.05}$
B (mm)	$1.27^{0}_{-0.5}$	$1.52^{0}_{-0.5}$	$1.75^{0}_{-0.5}$	$2.03^{0}_{-0.5}$	$2.54^{0}_{-0.5}$	$3.18^{0}_{-0.5}$	$5.69^{0}_{-0.38}$	$9.27^{0}_{-0.3}$
C(mm)[16]	3.17	3.81	4.31	4.57	6.35	8.76	14.8	22.9

Table 9. FSP with skirt launched without sabot characteristics "G"

Class	G5	G6	G7 [17]	G8 [18]
Caliber (mm)	**5.56**	**7.62**	**12.7**	**20**
Mass [g]	1.10 ± 0.03	2.85 ± 0.03	13.41 ± 0.13	53,78 ± 0,25
Diameter A (mm)	$5.46^{+0.02}_{0}$	$7.52^{0}_{-0.02}$	12.57 ± 0.02	$19.91^{0}_{-0.05}$
Diameter B (mm)	5.74 ± 0.02	7.85 ± 0.02	12.95 ± 0.02	$20.90^{0}_{-0.07}$
Diameter C (mm)	$5.08^{0}_{-0.25}$	$6.93^{0}_{-0.25}$	$11.43^{+0,07}_{-0.02}$	18.80 ± 0.12
D (mm)	$2.54^{0}_{-0.25}$	$3.45^{0}_{-0.50}$	$5.69^{0}_{-0.38}$	$9.27^{0}_{-0.30}$
E (mm)	6.35 ± 0.05	8.84 ± 0.05	14.78 ± 0.05	$23.16^{+0.25}_{0}$
F (mm)	0.64 ± 0.05	0.86 ± 0.05	1.47 ± 0.05	2,31 ± 0,05
G (mm) max	0.12	0.12	0.15	0.20
R (radius) (mm)	$6.35^{0}_{-0.76}$	$8.64^{0}_{-0.76}$	$14.73^{0}_{-0.76}$	$23.11^{0}_{-0.76}$
H (mm) [17]	6.53	8.99	14.89	23.7

Table 10. Right Circular Cylinders (RCC) characteristics (R1 to R7)

Class	R1	R2	R3	R4	R5	R6	R7
Mass [g]	0.16 ± 0.03	0.24 ± 0.03	0.33 ± 0.03	0.49 ± 0.03	1.10 ± 0.03	2.84 ± 0.03	4.15 ± 0.03
Diameter A (mm)	2.64 ± 0.27	3.25 ± 0.22	3.60 ± 0.19	4.06 ± 0.14	5.39 ± 0.06	7.49 ± 0.04	8.74 ± 0.03
B (mm) [17]	3.77	3.64	4.07	4.78	6.17	8.19	8.82

[16] Dimension must be adjusted to give correct weight
[17] Called G8 in current AEP 2920
[18] Called G9 in current AEP 2920

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In 1996, annex A to STANAG 2920 edition 2 [12] defined steel cylinders or RCCs. Mass, diameter and length values were put in a table for 7 RCC fragments. Masses range from 0.16 g to 4.15 g. In the current AEP 2920 [2] we can find same table. Only mass of 1.10 g RCC change in AEP 2920 by mistake but with same diameter and length (it could be mass of the US 16gr RCC?). It is important to notice that STANAG 2920 RCCs are different from US RCCs. Mass will be corrected in the next AEP and will be back to 1.10 g. Mechanical design office of DGA Land Systems built a drawing although it is not particularly difficult to understand steel cylinders but we can thus add some requirements for manufacturer. Table 10 presents values and tolerances for RCCs.

3. CONCLUSION

Reviewing fragments definition is clearly necessary to correct inconsistencies and mistakes and reduce irregular results from testing. Guidelines for quality controls will also improve acceptance and qualification processes for ballistic protection. Drawings and guidelines detailed here are proposed for the next AEP 2920 expected in 2021.

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