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## TECHNOLOGY OF MANUFACTURE OF FIREARMS IN THE TEUTONIC ORDER'S STATE IN PRUSSIA – GUN BARRELS AND METAL PROJECTILES

**Abstract:** The paper focuses on two issues related to the manufacture of firearms in the state of the Teutonic Order in Prussia: the technology of gun barrels and metal projectiles. According to written sources, among materials used for gun barrels in Prussia there were iron, bronze and copper. Furthermore, some records mention barrels cast from unspecified copper alloys. Data gathered from written sources are not fully representative for the entire period in question (i.e., the late 14<sup>th</sup>-early 16<sup>th</sup> c.), as they are the most complete only for the turn of the 14<sup>th</sup> and 15<sup>th</sup> c. However, some tentative conclusions can be made. One observes a preponderance of copper and its alloys over iron, which is especially notable for artillery. Almost all heavy cannons known from sources were cast from bronze. In contrast to many other regions of Europe, there is no evidence of manufacture of heavy guns from wrought iron bars and rims in the Order's state in Prussia. Furthermore, there is no information on the manufacture of cast iron barrels. This may testify to the fact that more attention was paid to quality than to cost saving.

Concerning details of manufacturing processes, available source data can be reasonably linked to what is known on the technology of casting of copper alloy cannon barrels based on 16<sup>th</sup> c. accounts. In contrast to hitherto beliefs, there is no evidence of casting of solid cannon barrels which were then bored. In some cases it was possible to tentatively assess (based on data concerning raw materials) the chemical composition of copper alloy gun barrels cast by the Order. The proportion of tin is the highest in the case of the heaviest guns. This data generally fits into what is known from other sources on the chemical composition of copper alloy barrels. Regrettably, there are hardly any mentions which would allow for a more detailed reconstruction of manufacturing technology of iron barrels. A special attention must be paid here to the record from 1411, mentioning the use of osmund (early blast furnace refined cast iron made in Sweden) for forging of gun barrels.

As regards metal projectiles, it seems that most of them were made from lead. These were chiefly missiles for hand-held firearms and light artillery. On the other hand, there are also few mentions on the manufacture of iron missiles. Among them, the most interesting one mentions casting of iron projectiles for terrace guns in 1412. However, it seems that cast iron cannonballs, which revolutionised the development of European artillery, appeared in the Order's state only at the turn of the 15<sup>th</sup> and 16<sup>th</sup> c.

**Keywords:** firearms, artillery, hand-held firearms, metal projectiles, ironworking, lead, copper alloys, technology, Prussia, Teutonic Order

### Introduction

Firearms in the state of the Teutonic Order in Prussia have been provoking researchers' interest for more than 100 years. One can mention here works by B. Engel<sup>1</sup>, B. Rathgen<sup>2</sup>, M. Grodzicka<sup>3</sup>, V. Schmidtchen<sup>4</sup>, studies by A. Nowakowski<sup>5</sup>, M. Woźniak<sup>6</sup>, M. Arsyński and

I. Sikorska-Ulfik<sup>7</sup>, W. Świętosławski<sup>8</sup>, A. R. Chodyński<sup>9</sup>, M. Dąbrowska<sup>10</sup>, G. Żabiński<sup>11</sup> or G. Żabiński and P. Muntowski<sup>12</sup>. Valuable remarks on firearms in the Teutonic Order's state can be also found in works concerning firearms

<sup>1</sup> Engel 1897-1899, 195-199, 228-233.

<sup>2</sup> Rathgen 1922; Rathgen 1924, 45-76; Rathgen 1928.

<sup>3</sup> Grodzicka 1960, 358-415; Grodzicka 1963, 7-13.

<sup>4</sup> Schmidtchen 1977a.

<sup>5</sup> Nowakowski 1986b, 43-60; Nowakowski 1994a; Nowakowski 1994b; Nowakowski 2004.

<sup>6</sup> Woźniak 1990, 70.

<sup>7</sup> Arsyński and Sikorska-Ulfik 1990, 70-71.

<sup>8</sup> Świętosławski 1993, 19-31.

<sup>9</sup> Chodyński 1978; Chodyński 1996a, 15-24; Chodyński 1997, 69-79; Chodyński 2007, 388-389; Chodyński 2010a, 126-127; Chodyński 2010b, 181-200.

<sup>10</sup> Dąbrowska 2007, 303-316.

<sup>11</sup> Żabiński 2011, 505-514; Żabiński 2013, 199-212; Żabiński 2014, 119-142.

<sup>12</sup> Żabiński and Muntowski 2013, 37-58.

or weaponry in general in what is now Poland and in Central Europe<sup>13</sup>.

There is also a group of publications specifically devoted to issues of technology of firearms. One can mention here the work of M. Dąbrowska<sup>14</sup>, dealing with results of archaeological excavations in the area of the foundry in the Fore-Castle in Marienburg (Malbork)<sup>15</sup> and attempting at reconstructing the process of gun casting, a study of the famous light field cannon from the castle of Kurzętnik (Kauernik)<sup>16</sup>, or a paper on the Teutonic *Grose Bochse* cast in 1408<sup>17</sup>.

The aim of this paper is to discuss two issues concerning the technology of manufacture of firearms in the Teutonic Order's state in Prussia (with auxiliary data concerning the Order's castles in Livonia), namely, the technology of gun barrels and metal projectiles (bullets and cannonballs, excluding so-called *bochsenspfyle* or gun bolts). The paper is divided into the following sections:

1. general data on raw materials used for gun barrels and metal projectiles in the Order's state
2. general data on the technology of gun barrel manufacture in the discussed period
3. technology of gun barrel manufacture in the Order's state
4. technology of metal gun projectiles manufacture in the Order's state

Concerning the chronological scope of the paper, it mainly focuses on the period between the end of the 14<sup>th</sup> c. and c. 1420. It is for this period that the source basis is the most comprehensive, also including account book sources.

With regard to the source basis, a treatise by Vannoccio Biringuccio from 1540<sup>18</sup> must be mentioned. Apart from offering extensive discussion on non-ferrous and ferrous metallurgy, it also devotes much attention to gun and projectile manufacture. It was also decided to consult the manual by J. Jakubowski<sup>19</sup>, as this work was used in her paper by M. Dąbrowska<sup>20</sup>.

Concerning other sources, these concerning the Teutonic Order as such are of the greatest importance. One must first of all mention Teutonic account books. The most significant one is the account book of the Order's Treasurer<sup>21</sup>, spanning the period of 1399-1409. Interesting pieces of data

on firearms can be also found in the book of the Marienburg (Malbork) Convent for 1399-1412<sup>22</sup>, as well as in the expense book of the House Commander of Marienburg (Malbork)<sup>23</sup>, which covers the period of 1410-1420. Relevant data can also be retrieved from the Order's inventories and visitation reports<sup>24</sup>. Much less account data is regrettably available for Prussian towns. One must mention here the account books of the Old Town of Elbing (Elbląg)<sup>25</sup> and of Toruń (Thorn)<sup>26</sup>. In some cases relevant data on firearms can be retrieved from accounts which came into existence for the needs of the Prussian Confederacy during the Thirteen Years War (1454-1466) against the Order<sup>27</sup>. Furthermore, interesting data can sometimes be found in narrative sources<sup>28</sup>. Relevant pieces of information can also be retrieved from extracts of sources from the *Ordensbriefarchiv*<sup>29</sup>.

Finally, it is worth offering some data on the monetary and weight system which was used in Prussia at that time. This information is based on sources and scholarship used in this paper.

Currency:

1 Mark – 4 Ferto (Vierdung) – 24 Scots – 60 Schilling (shillings) – 720 Denars

Weights:

1 Last – 12 Tonnen (barrels) – 12 Schiffspfund (skippounds) – 36 Zentner – 240 Lispfund (lispounds) – 4320 Pfund (pounds)

1 Stein (stone) – 34 Pfund in Gdańsk (Danzig) and Elbing (Elbląg), 24 Pfund in Toruń (Thorn)

1 pound – c. 0.405 kg

### Raw materials for gun barrels and projectiles

Inventories and visitation reports mention gun barrels made from the following kinds of raw materials:

Iron:

- 6 iron guns (*yserynne buchszen*) in the Commandery of Toruń (Thorn) in 1392 and 1397<sup>30</sup>
- 2 iron lead bullet guns (*yserynne lothbuchszen*) in the Reeveship of Brattian (Bratian) in 1405<sup>31</sup>

<sup>13</sup> E.g., Konieczny 1964, 167-237; Głosek 1990, 155-164; Mielczarek 1998a, 60-64; Mielczarek 1998b, 65-72; Szymczak 2004; Strzyż 2011; Strzyż 2014.

<sup>14</sup> Dąbrowska 2009, 21-44.

<sup>15</sup> It was decided to use original historical local names first, while later names are given in parentheses, therefore: Gdańsk (Danzig), but Marienburg (Malbork).

<sup>16</sup> Stępiński *et al.* 2013, 155-202; for technological analyses of firearms from Poland see also Klimek *et al.* 2013, 83-98.

<sup>17</sup> Żabiński 2012, 31-40.

<sup>18</sup> V. Biringuccio, *The Pirotechnia*.

<sup>19</sup> *Nauka Artylerji*.

<sup>20</sup> Dąbrowska 2009.

<sup>21</sup> MTB.

<sup>22</sup> MKB.

<sup>23</sup> ABMH.

<sup>24</sup> Visitationen 1; Visitationen 2; GÄDO; MÄB; for a discussion on the nature and value of these sources see, e.g., Żabiński 2011; Żabiński 2013; Stępiński *et al.* 2013, 164-165.

<sup>25</sup> NKRSME 1; NKRSME 2.

<sup>26</sup> KKMT.

<sup>27</sup> KT; KŻZP; Biskup 1966, 81-94.

<sup>28</sup> *Preussische Chronik 1; Preussische Chronik 2; Posilge, Chronik; Die Danziger Chronik vom Bunde...; Die Ferber-Chronik*, pp. 529-543.

<sup>29</sup> Regesta.

<sup>30</sup> GÄDO, p. 429-430; Rathgen 1922, 7; Rathgen 1928, 394; Nowakowski 2004, 227.

<sup>31</sup> GÄDO, p. 365.

- 2 iron lead bullet guns (*yserynne lothbuchszen*) in the Commandery of Człuchów (Schlochau) in 1410<sup>32</sup>
- 1 iron stone cannonball gun (*yserinne steynbuchse*) in the Commandery of Świecie (Schwetz) in 1411<sup>33</sup>
- 3 iron guns (*yseryn buchszen*) in the Commandery of Königsberg (Kaliningrad) in 1414<sup>34</sup>
- 15 stone cannonball guns of various size, some of which were made from iron (*steynbochszen gros und cleyn ysern und gegossen*) in the Commandery of Königsberg (Królewiec) in 1415<sup>35</sup>
- 2 iron (*yserynne*) lead bullet gun (*lothbochszen*) in the Commandery of Brandenburg (Ušakovo) in 1418<sup>36</sup>
- 4 unusable iron lead bullet guns (*loethbochszen dy togen nicht und seynt gesmytd von eyszer*) in Gerdauden (Železnodorožny), the Procurator's Office in the Commandery of Königsberg (Kaliningrad) in 1420<sup>37</sup>
- 1 iron gun (*eyserinne buchse*) in the Commandery of Golub (Gollub) in 1421<sup>38</sup>
- 4 iron guns (*yserynne bochszen*) in the Commandery of Königsberg (Kaliningrad) in 1422. In 1424, 4 iron lead bullet guns were mentioned (*yserynne lothbuchszen*)<sup>39</sup>
- 5 iron lead bullet guns (*ysern lodbuchszen*) in the castle of Driesen (Drezdenko) in the Reeveship of Neumark in 1428<sup>40</sup>
- 2 iron guns (*eyserinne bochszen*) and 8 iron lead bullet guns (*eyserene lothbuchszen*) in the Commandery of Nowa Nieszawa (Nessau) in 1431. There were 9 iron lead bullet guns in 1432 and again 8 in 1434. In 1432, 1434 and 1435 there were 3 iron stone cannonball guns (*iseren steynbuchszen*) there<sup>41</sup>
- 4 barrels of osmund iron (*vas osemundes*) were mentioned among gun resources in the Commandery of Christburg (Dzierzgoń) in 1434<sup>42</sup>
- 4 iron guns (*eyserinn buchszen*) in the Commandery of Memel (Klaipėda) in 1434<sup>43</sup>
- 4 iron lead bullet guns (*eysern lodbuchszen*) in the Commandery of Starogród (Althausen) in 1434<sup>44</sup>
- 4 iron guns (*ysern buchszen*) in the Commandery of Ragnit (Neman) in 1437<sup>45</sup>
- 2 iron lead bullet guns (*eyssirn loutbuchszen*) in the Reeveship of Stuhm (Sztum) in the Commandery of Marienburg (Malbork) in 1437. 1 such gun was recorded in 1440, while in 1446 there were 2 such guns again<sup>46</sup>
- 4 iron guns (*yserynn buchszen*) in the Reeveship of Grabin (Grebin) in the Commandery of Marienburg (Malbork) in 1437. Based on records from preceding and following years it can be proposed that these were lead bullet guns<sup>47</sup>
- 1 iron gun (*eyserynne buchse*) in the Commandery of Świecie (Schwetz) in 1440<sup>48</sup>
- 4 iron guns (*eysern buchszen*) at the castle of Ortelsburg (Szczytno) in the Commandery of Elbing (Elbląg) in 1440<sup>49</sup>
- 5 iron veuglaires (*eyserne fogeler*), 2 iron stone cannonball guns (*eyserne steynbochszen*), and 4 iron lead bullet guns (*eyserne lothbochszen*) in the castle of Reval (Tallin) in Livonia in 1451<sup>50</sup>
- an unspecified number of iron handgonnes (*eyserne hantbochszen*) in the castle of Marienburg (Alūksne) in Livonia in 1451<sup>51</sup>
- 1 iron lead bullet gun (*eiserne lothbouchze*) was sent from Toruń (Thorn) to Golub (Gollub) in 1455 to support the troops of the Prussian Confederacy<sup>52</sup>
- 1 iron gun (*eysern bouchse*) was mentioned in the equipment of the Prussian Confederacy troops besieging Świecie (Schwetz) in 1461<sup>53</sup>
- 1 iron gun (*eisern buchse*) in the Reeveship of Soldau (Działdowo) in the Commandery of Osterode (Ostróda) in 1479<sup>54</sup>
- 4 iron stone cannonball guns (*eisern steinbuchszen*) in the Procurator's Office of Ortelsburg (Szczytno) in 1507 and 1508<sup>55</sup>
- 2 iron naval veuglaires (*eisern schifbuchszen mit camern*) in the Procurator's Office of Szestno (Sehesten) in the Commandery of Balga (Veseloe) in 1507 and 1508<sup>56</sup>
- 4 iron guns (*eisern buchszen*) in the Procurator's office of Johannsburg (Pisz) in the Commandery of Balga (Veseloe) in 1507 and 1508<sup>57</sup>
- 1 iron hackbut (*eisen hockenpuchse*), 2 small iron guns (*clein eise buchszen*) and 4 large iron guns (*gros eise buchszen*) in the Commandery of Holland (Pasłęk) in 1518<sup>58</sup>
- 4 iron stone cannonball guns (*eiser steinbuchszen*) at the castle of Mohrunen (Morąg) in 1518<sup>59</sup>

<sup>32</sup> GÄDO, p. 650; Strzyż 2011, 117.

<sup>33</sup> GÄDO, p. 616; Stepiński et al. 2013, 178.

<sup>34</sup> GÄDO, p. 14.

<sup>35</sup> GÄDO, p. 16.

<sup>36</sup> GÄDO, p. 221; Stepiński et al. 2013, 177.

<sup>37</sup> GÄDO, p. 68.

<sup>38</sup> GÄDO, p. 404.

<sup>39</sup> GÄDO, p. 18, 21, 26.

<sup>40</sup> GÄDO, p. 771; Stepiński et al. 2013, 178.

<sup>41</sup> GÄDO, p. 483-486; Rathgen 1922, 11, 13; Rathgen 1928, 397-398; Stepiński et al. 2013, 177; Strzyż 2014, 224.

<sup>42</sup> GÄDO, p. 141.

<sup>43</sup> GÄDO, p. 309.

<sup>44</sup> GÄDO, p. 506; Stepiński et al. 2013, 178.

<sup>45</sup> GÄDO, p. 287.

<sup>46</sup> MÄB, p. 19, 21, 23.

<sup>47</sup> MÄB, p. 30-35, 38-39.

<sup>48</sup> GÄDO, p. 630.

<sup>49</sup> GÄDO, p. 100.

<sup>50</sup> Visitationen 2, p. 31, No. 147; Klimek et al. 2013, 93.

<sup>51</sup> Visitationen 2, p. 38, No. 147.

<sup>52</sup> Biskup 1966, 87, 91.

<sup>53</sup> Biskup 1966, 88; Biskup 1967, 578.

<sup>54</sup> GÄDO, p. 351.

<sup>55</sup> GÄDO, p. 118, 120.

<sup>56</sup> GÄDO, p. 189-190; Klimek et al. 2013, 93.

<sup>57</sup> GÄDO, p. 208.

<sup>58</sup> GÄDO, p. 111-112.

<sup>59</sup> GÄDO, p. 113-115.

- 5 iron lead bullet guns (*eysennbuechsen mit loeth*) in the Procurator's Office of Ortelsburg (Szczytno) in 1519<sup>60</sup>
- 3 iron guns on carriages (*eysereenn buchsen off karenn*) in the Procurator's Office of Ortelsburg (Szczytno) in 1521<sup>61</sup>
- 1 iron gun (*eisere puchsz*) and 13 iron handgonnes (*eisere hantruer*) in the Procurator's Office in Preussisch Mark (Przezmark) in 1521<sup>62</sup>
- 1 large iron gun (*grose eyserne buchs*) and 2 iron serpentines (*eyserne schlangen*) in the Commandery of Memel (Klaipeda) in the period of 1511-1525<sup>63</sup>
- 2 iron serpentines (*eyssern schlengken*) were recorded in Balga (Veseloe) by the anonymous author of the Teutonic Order's firearms inventory, dated to about 1523<sup>64</sup>

Bronze<sup>65</sup>:

- 2 small bronze lead bullet (*cleyne erynne lotbuchsen*) in the Commandery of Człuchów (Schlochau) in 1410<sup>66</sup>
- 1 bronze (*erynne*) lead bullet gun (*lothbochse*) in the Commandery of Brandenburg (Ušakovo) in 1418<sup>67</sup>
- 4 bronze (*eren*) lead bullet guns (*lotbuchsen*) in the Commandery of Nowa Nieszawa (Nessau) in 1432<sup>68</sup>
- 3 bronze stone cannonball guns (*eren steynbuchsen*) and 1 such veuglaire with two powder chambers (*I mit czwen camern*) in the Commandery of Nowa Nieszawa (Nessau) in 1432<sup>69</sup>
- 42 bronze guns (*eren buchsen*) in the Commandery of Gniew (Mewe) in 1438 and 1440. Based on the record from 1437, it can be said that these were lead bullet guns. In 1441, 40 *eren buchsen* were mentioned, while the record from 1442 mentioned simply 42 lead bullet guns<sup>70</sup>
- 3 bronze guns (*eren buchsen*) at the castle of Ortelsburg (Szczytno) in the Commandery of Elbing (Elbląg) in 1440<sup>71</sup>
- 2 bronze lead bullet guns (*erene lothbochzen*), 1 bronze veuglaire (*eren fogeler*), and 1 bronze stone cannonball gun (*eren steynbochze*) in the castle of Reval (Tallin) in Livonia in 1451<sup>72</sup>
- 1 large bronze gun (*grosze erenne bochsze*) in the castle of Narva in Livonia in 1451<sup>73</sup>
- 2 bronze veuglaire (*erene fogeler*) in the castle of Weissenstein (Paide) in Livonia in 1451<sup>74</sup>
- an unspecified number of small bronze guns (*erene bochzen cleyne*) in the castle of Marienburg (Alūksne) in Livonia in 1451<sup>75</sup>
- 2 bronze stone cannonball guns (*eren steinbuchssen*) in the Procurator's Office of Ortelsburg (Szczytno) in 1507 and 1508<sup>76</sup>

## Copper:

- 2 small copper stone cannonball gun (*cleyne kopperinne steynbuchsen*) in the Commandery of Świecie (Schwetz) in 1411<sup>77</sup>
- 21 copper stone cannonball guns (*kopperynne steinbuchsen*) in the Town Hall of the Old Town of Elbing (Elbląg) in 1413<sup>78</sup>
- 10.5 stones of copper from two broken guns (*copper von czwen czubrachen bochsen die heuwer sind czubrachen*) were recorded in the Commandery of Tuchola (Tuchel) in 1422<sup>79</sup>
- 1 copper terrace gun (*kopperen tarrasbochse*) and 1 copper lead bullet gun (*kopperene lotbuchse*) in the Commandery of Nowa Nieszawa (Nessau) in 1431<sup>80</sup>
- 9 copper (*copperne*) lead bullet guns (*lotbuchsen*) in the Commandery of Nowa Nieszawa (Nessau) in 1432 and 1434<sup>81</sup>
- 4 copper stone cannonball guns (*kopperynne steynbochsen*) and 1 such terrace gun (*tharresbochse*) in the Commandery of Nowa Nieszawa (Nessau) in 1435<sup>82</sup>
- 13 copper lead bullet guns (*copperrn lotbuchsen*) in the Commandery of Starogród (Althausen) in 1434<sup>83</sup>
- 9 copper lead bullet guns (*loethbuchsen kopperrn*) in the Reeveship of Stuhm (Sztum) in the Commandery of Marienburg (Malbork) in 1437. These guns were also recorded in 1440 and 1446, together with 1 small copper gun (*cleyne koppirn buchse or buchschn*)<sup>84</sup>
- 3 copper semi-terrace guns (*kopperrn halbe tarnischbuchsen*) in the Commandery of Memel (Klaipeda) in the period of 1511-1525<sup>85</sup>

<sup>60</sup> GÄDO, p. 121.<sup>61</sup> GÄDO, p. 123.<sup>62</sup> GÄDO, p. 149.<sup>63</sup> GÄDO, p. 314.<sup>64</sup> Biskup 1984, 102.<sup>65</sup> In one of his previous papers (Stępiński et al. 2013), G. Żabiński rather carelessly assumed that the term *ehern* (or *eren*, *erenn*, *erynn*) should unequivocally stand for red brass. It is never too late to admit and correct one's own mistakes.<sup>66</sup> GÄDO, p. 650; Strzyż 2011, 117.<sup>67</sup> GÄDO, p. 221; Stępiński et al. 2013, 178.<sup>68</sup> GÄDO, p. 484; Stępiński et al. 2013, 178.<sup>69</sup> GÄDO, p. 485; Strzyż 2014, 102; Rathgen 1922, 11, 13; Rathgen 1928, 398.<sup>70</sup> GÄDO, p. 750-751, 753-754, 756; Stępiński et al. 2013, 178.<sup>71</sup> GÄDO, p. 100; Stępiński et al. 2013, 178.<sup>72</sup> Visitationen 2, p. 31, No. 147.<sup>73</sup> Visitationen 2, p. 31, No. 147.<sup>74</sup> Visitationen 2, p. 34, No. 147.<sup>75</sup> Visitationen 2, p. 38, No. 147.<sup>76</sup> GÄDO, p. 118, 120.<sup>77</sup> GÄDO, p. 616; Stępiński et al. 2013, 178<sup>78</sup> EK, pp. 223-273; Rathgen 1922, 72; Rathgen 1928, 429; Chodyński 1997, 77-78; Chodyński 1996a, 20, 22; Strzyż 2011, 115; Stępiński et al. 2013, 180.<sup>79</sup> GÄDO, p. 642; Rathgen 1922, 11; Rathgen 1928, 397; Żabiński 2014, 122.<sup>80</sup> GÄDO, p. 483; Stępiński et al. 2013, 178.<sup>81</sup> GÄDO, p. 484-485; Rathgen 1922, 11; Rathgen 1928, 397; Strzyż 2014, 224.<sup>82</sup> GÄDO, p. 485-485; Stępiński et al. 2013, 176, 178.<sup>83</sup> GÄDO, p. 506; Stępiński et al. 2013, 178.<sup>84</sup> MÄB, p. 19, 21, 23.<sup>85</sup> GÄDO, p. 314.

Brass:

- about 60 hackbuts with brass barrels (*mesigkes hacken*) were recorded in Königsberg (Kaliningrad) by the anonymous author of the Teutonic Order's firearms inventory, dated to about 1523<sup>86</sup>
- 23 brass hackbuts (*mesingks hacken*) and 28 brass handgonnes (*mesingks handror*) were brought from Riesen- burg (Prabuty) to Preussisch Mark (Przezmark) upon the request of the anonymous author of the Teutonic Order's firearms inventory, dated to about 1523<sup>87</sup>

Unspecified copper alloy:

- 10 stone cannonball guns (*steynbuchsen*) were mentioned in the Commandery of Człuchów (Schlochau) in 1413. Based on the mention that one of these was damaged and its metal was referred to as *spyse* (*eyne ist zubrochen die spyse lyt noch do*) it can be assumed that it was some kind of copper alloy<sup>88</sup>
- 1 stone cannonball (*steynbuchse*) was mentioned in the resources of the Commandery of Pokrzywno (Engelsberg) in 1414. It was stated that the gun was in Toruń (Thorn) at that time and it should be cast again (*die sal man weder gisen*)<sup>89</sup>
- 15 stone cannonball guns of various size, some of which were cast from non-ferrous metal (*steynbuchsen gros und cley ynsern und gegossen*) in the Commandery of Königs- berg (Królewiec) in 1415<sup>90</sup>
- 4.5 Zentners of copper (*koppir*) were recorded in the castle crossbow workshop of the Commandery of Gniew (Mewe) in 1416 and in 1422, together with guns, gunpow- der, crossbows and bullets. Another inventory from 1422 mentioned 1 barrel of copper and 1 disc (?) (*1 tonne kop- pir und 1 schiebe*). It could be perhaps assumed that the metal was supposed to be used for gun casting<sup>91</sup>
- 19 Zentners of copper alloy referred to as *glockspeise* were recorded in the castle crossbow's workshop (*snic- zhuws*) of the Commandery of Christburg (Dzierzgoń) in 1432<sup>92</sup>
- 1 small cast guns on a carriage (*clein gegossen stuck uff einen karrn*) in the Procurator's Office of Ortelsburg (Szczytno) in 1521. This inventory also recorded 3 iron guns on carriages<sup>93</sup>
- 4 quarter-serpentines (*quartirschlängen*), each weighing 4 Zentners, and 1 small falconet (*falckenmethlen*) weigh- ing 5 Zentners were ordered to be cast (*gyessen*) by the anonymous author of the Teutonic Order's firearms inven- tory, dated to about 1523<sup>94</sup>.

It could be asked to what extent this data can be sub- ject to a quantitative analysis. It must be remembered that in a majority of cases inventories and visitation reports did not mention the raw material a given gun was made from. Therefore, any conclusions concerning a preference for a given metal may not be quite representative. Further- more, in some cases it cannot be said for certain whether records of the same office from different years mention the same guns or not. Some guns mentioned in different years in the same place may have been new ones, intended to replace lost items. Moreover, in some cases a classifica- tion of a given guns into a certain type is rather specula- tive. A basic division between *steinbuchsen* and *lotbuchsen* which can be roughly (but not always, as stone projectiles could be used for hand-held firearms and metal projectiles for light artillery) understood as a division between artil- lery and hand-held firearms or very light cannons, must be of much less validity in the late 15<sup>th</sup> and early 16<sup>th</sup> c., when cast iron cannonballs went into use<sup>95</sup>. Therefore, in the sub- sequent analysis guns will be classified either as artillery or hand-held firearms/very light cannons. Eventually, the set of data concerning hand-held firearms is very strongly influenced by the anonymous inventory from about 1523, which mentions a great number of brass guns. Bearing these reservations in mind, one can attempt at drawing some general conclusions (Tab. 1).

The first observation is that both for artillery and hand- held guns (or very light cannons) there is a preponderance of copper and its alloys over iron, in spite of the obviously higher price of the former<sup>96</sup>. Of course, this result is heav- ily influenced by 111 brass hand-held guns from c. 1523, but even without taking them into consideration, the role of copper and its alloys is notable. The preponderance of non- ferrous metals is especially noteworthy for artillery. This seems to demonstrate that more attention was paid to qual- ity than to cost saving, especially in the case of larger guns, exposed to a greater stress caused by heavy gunpowder charges. Among non-ferrous metals, it seems that in general a slight preference was given to copper than to its alloys. A good example of a light field cannon made from antimo- ny copper is the famous cannon from Kurzętnik (Kauernik), dated to the early 15<sup>th</sup> c.<sup>97</sup>. On the other hand, one can see a preponderance of bronze in the group of hand-held guns.

Interestingly, P. Strzyż says that in Central Europe cop- per alloy barrels prevailed over wrought iron ones until the

<sup>86</sup> Biskup 1984, 101; Szymczak 2004, 41.

<sup>87</sup> Biskup 1984, 101.

<sup>88</sup> GÄDO, p. 652; Rathgen 1922, 12; Rathgen 1928, 398.

<sup>89</sup> GÄDO, p. 589, Rathgen 1922, 12; Rathgen 1928, 397.

<sup>90</sup> GÄDO, p. 16.

<sup>91</sup> GÄDO, p. 744, 746-747.

<sup>92</sup> GÄDO, p. 138.

<sup>93</sup> GÄDO, p. 123.

<sup>94</sup> Biskup 1984, 100-101.

<sup>95</sup> For this issue see also Strzyż 2011, 65; Strzyż 2014, 29, 72, 82, 111-115, 117, 130-134.

<sup>96</sup> A similar observation for the period of 1413-1446 was made by B. Rathgen, see Rathgen 1922, 11-12; Rathgen 1928, 397, 409, 414, 430.

<sup>97</sup> Grodzicka 1960, 369-370, No. 1; Grodzicka 1963, 7-13; Chodyński 2007, 388-389; Chodyński 2010a, 126-127; Strzyż 2011, 33-36, 123, Tab. 1A, cat. No. 5, Figs. IX-X; Stepiński et al. 2013, 155-163, 182, Fig. 37, 184, Fig. 38, 185-186; Strzyż 2014, 85-87, 217-218, 224, cat. No. 102, Figs. LXXXIV-LXXXV.

Artillery guns – 85 (100%)	Hand-held guns, very light cannons – 257 (100%)	Unspecified – 43 (100%)
iron – 30 (35.29%) bronze – 8 (9.41%) copper – 30 (35.29%) brass – unspecified Cu alloy – 17 (20.00%) total Cu and its alloys – 55 (64.71%)	iron – 62 (24.12%; 42.47%**) bronze – 51 (19.84%; 34.93%**) copper – 33 (12.84%; 22.60%**) brass* – 111 (43.19%) unspecified Cu alloy – total Cu and its alloys – 195 (75.88%) (84 – 57.53%**)	iron – 33 (76.74%) bronze – 6 (13.95%) copper – 4 (9.30%) brass – unspecified Cu alloy – total Cu and its alloys – 10 (23.26%)
<b>Total all: 385 (100%)</b> Total iron: 125 (32.47%; 45.62%**) Total bronze: 65 (16.88%; 23.72%**) Total copper: 67 (17.40%; 24.45%**) Total brass: 111 (28.83%) Total unspecified Cu alloy: 17 (4.42%; 6.20%**) Total Cu and its alloys: 260 (67.53%) (149 – 54.38%**)  * all brass hand-held guns were recorded in the Teutonic Order's inventory c. 1523 ** without taking brass hand-held guns into consideration  Sources: GÄDO, p. 14, 16, 18, 21, 26, 68, 100, 111-115, 118, 120-121, 123, 141, 149, 189-190, 208, 221, 287, 309, 314, 351, 365, 404, 429-430, 483-486, 506, 589, 616, 630, 642, 650, 652, 750-751, 753-754, 756, 771; MÄB, p. 19, 21, 23, 30-35, 38-39; <i>Visitationen</i> 2, p. 31, 34, 38, No. 147; EK, p. 253; Biskup 1966, 87-88, 91; Biskup 1984, 101-103; KKMT, No. 15		

Tab. 1. Raw materials in guns in the Teutonic Order's state (the late 14<sup>th</sup>-early 16<sup>th</sup> c.) according to inventories and visitation reports.  
Author: G. Żabiński.

mid-15<sup>th</sup> c. He also maintains that the significance of hand-held iron firearms compared to bronze ones increased in Central Europe from c. 1450<sup>98</sup>. L. Makovskaya says that the late 14<sup>th</sup>-15<sup>th</sup> c. hand-held firearms in Rus were made from iron<sup>99</sup>. B. Rathgen states that in the first half of the 15<sup>th</sup> c. in Frankfurt am Main copper was preferred for burgher hand-held firearms. He states that this was due to the fact that copper, although it was not able to withstand stronger powder charges, was still less prone to breaking than bronze<sup>100</sup>. A preponderance of bronze hand-held guns over iron ones was also noticed by this scholar for the town of Hildesheim in the first half of the 15<sup>th</sup> c.<sup>101</sup>. On the other hand, while the register of firearms in the fortifications of the city of Köln from 1446 mentioned 62 copper guns and 80 iron guns, the register from 1468 mentioned 63 copper guns and 103 iron guns, which means a more than 25% increase in the number of iron firearms<sup>102</sup>. Furthermore, B. Rathgen also noticed a dominance of iron hand-held firearms in the 1<sup>st</sup> half of the 15<sup>th</sup> c. in Burgundy<sup>103</sup>. However, for the period of 1420 to 1465 R. D. Smith and K. DeVries say that the number of copper alloy and iron hand-held *coulovrines* was more or less equal<sup>104</sup>. Concerning artillery, B. Rathgen said that in the Burgundian town of Dijon in the second half of the

14<sup>th</sup> c. cannons were mainly made from copper<sup>105</sup>. With regard to Spain, this author gives an example of the collection of about 30 stone cannonball guns from the collection of the Artillery Museum in Madrid, which are dated to the 14<sup>th</sup>-early 16<sup>th</sup> c. and are all made from wrought iron<sup>106</sup>. A preponderance of iron can also be seen in the case of Burgundian *veuglaires* in the period of 1417-1467<sup>107</sup>. In Central Europe, P. Strzyż identified 15 examples of 15<sup>th</sup> c. terrace guns (such guns could be classified both as *steynbuchsen* and *lotbuchsen* in written sources), out of which 14 were made from iron and one from copper alloy. On the other hand, this scholar says that according to written sources bronze or copper barrels of such guns were much more common in the first half of the 15<sup>th</sup> c. and a preponderance of iron barrels can be seen only after c. 1450<sup>108</sup>.

It is worth comparing this set of data with pieces of information concerning the manufacture and purchase of new firearms. Most obviously, as in the case of inventories and visitation reports, the lion's share of this data concerns the Order itself. Furthermore, most of this data comes from a narrow period of the early 15<sup>th</sup> c. These pieces of information are the following:

- transportation of 3 Zentners of copper (*kopper*) for small guns (*zu den cleynen bochsen*) in 1401 from Gdańsk (Danzig) to the Order's capital<sup>109</sup>

<sup>98</sup> Konieczny 1964, 183; Szymczak 2004, 100; Klimek et al. 2013, 93-94; Strzyż 2014, 47, 213-214.

<sup>99</sup> Makovskaya 1992, 24-25, 36, 38-39; Strzyż 2014, 30.

<sup>100</sup> Rathgen 1928, 68-71.

<sup>101</sup> Rathgen 1928, 301-304.

<sup>102</sup> Rathgen 1928, 316, 454.

<sup>103</sup> Rathgen 1928, 534-536.

<sup>104</sup> Smith and DeVries 2005, 217.

<sup>105</sup> Rathgen 1928, 555-556.

<sup>106</sup> Rathgen 1928, 566-571.

<sup>107</sup> Smith and DeVries 2005, 234.

<sup>108</sup> Strzyż 2014, 73-81.

<sup>109</sup> MTB, p. 99; Engel 1897-1899, 230; Rathgen 1922, 22; Rathgen 1928, 403; Żabiński 2014, 121.

- transportation of 1.5 stones and 3 pounds of tin (*zen*) and 6.5 Zentners of copper (*kopper*) for guns (*buchsen*) from Gdańsk (Danzig) to the Order's capital in 1401. Another transport in that year included 5 Zentners of copper. Then, casting of 6 guns (*buchsen*) with a total weight of 15 Zentners was mentioned, at a price of 15 Marks (1 Mark per 1 Zentner)<sup>110</sup>. The weight of purchased metal is almost equal to the total weight of guns. It can be thus naturally assumed that this metal formed copper alloy (in this case, bronze) which was used for casting of these 6 guns. If their weight was equal, they were naturally stone cannonball guns
  - payment of 24 Marks to a smith (*smed*) Molner for making 12 iron guns (*yserynne buchsen*) in 1401<sup>111</sup>. The number of guns compared with the amount of money seems to suggest hand-held firearms
  - casting of 2 guns containing 5 Zentners and 15 Scot pounds of tin (GŽ – it should be perhaps 5 Zentners of copper and 15 Scot pounds of tin) at the end of 1401 at the castle of Marienburg (Malbork)<sup>112</sup>. These guns were evidently stone cannonballs made from bronze
  - 3 Marks minus 1 Ferto were paid in 1402 for casting 2 guns anew, including the price of copper, tin and other work, at the castle of Malbork (Marienburg) (*vor zwu buchsen von nuwes wider zu gysen und vor koppir zeen und vor ander arbeyt zu den buchsen*)<sup>113</sup>. It is hard to say how much of the price went for raw materials and how much for labour expenses. Furthermore, this record strongly implies re-use of raw material from damaged guns. Anyway, bearing in mind the afore-mentioned price of 1 Mark for casting of 1 Zentner, one may assume that this mention implies bronze stone cannonball guns
  - casting of 2 guns (*buchsen*) at the castle of Marienburg (Malbork) in 1403. These guns (veuglaires with 3 powder chambers) weighted 4 Zentners and 20 pounds altogether. This record is preceded with a mention of a purchase of 4 Zentners and 0.5 stone of copper (*kopper*) and of 0.5 Zentner and 1 *krompfunt* of tin (*zen*) for gun casting<sup>114</sup>.
- It can be thus assumed that this record concerns casting of stone cannonball guns with the use of bronze
- payment of 9 Marks for 1 veuglaire with 3 chambers in 1404 to the smithing master (*smedemeister*) at the castle of Marienburg (Malbork)<sup>115</sup>. The person of the smithing master suggests that it was an iron gun, and the price seems to imply a small stone cannonball ordnance
  - purchase of 4 copper lead bullet guns (*kopperyne lodt-buchsen*), weighing 8 stones and 2 pounds altogether, for 9.5 Marks 6 shillings by the House Commander of Marienburg (Malbork) in 1405<sup>116</sup>
  - purchase of 8 iron bars for guns (*ysern schenen vor bus-sen*) by the authorities of the Old Town of Elbing (Elbląg) in 1406<sup>117</sup>
  - series of expenses for the casting of a supergun called the *Grose Bochse* in 1408. Among acquired raw materials used to cast the chase and the breech (this gun had a powder chamber) there was copper (*kopper*), tin (*zeen*) and lead (*bly*)<sup>118</sup>
  - payment of 8 Marks to the smithing master (*smedemey-ster*) at the castle of Marienburg (Malbork) in 1408 for 1 iron stone cannonball gun (*yserynne steynbochse*)<sup>119</sup>
  - payment of 85.5 Marks to a bell-founder (*glockengisser*) Heinrich Dumechen in 1408 for two medium-sized guns (*mittelbochsen*). Each weighted 9.5 Zentners, so these were obviously stone cannonball guns. Concerning the raw material, only copper is mentioned in this record. A considerable sum paid for these guns was also result of the fact that it had to cover costs of raw materials and charcoal, apart from labour expenses<sup>120</sup>
  - series of expenses for casting of a small long gun (*cleyne lange bochse*) with 3 powder chambers (*polfergehusen*) in Gdańsk (Danzig) in 1409. Among raw materials there was copper (*kopper*), tin (*zeen*) and lead (*bly*). The weight

<sup>110</sup> MTB, p. 119-120; Engel 1897-1899, 230; Rathgen 1922, 23; Rathgen 1928, 403-404; Schmidtchen 1977a, 54; Świętosławski 1993, 21; Stępiński et al. 2013, 173; Żabiński 2014, 121, 128.

<sup>111</sup> MTB, p. 119; Engel 1897-1899, 230; Rathgen 1922, 23; Rathgen 1928, 403, 409; Schmidtchen 1977a, 62; Chodyński 1978, 15; Świętosławski 1993, 22; Nowakowski 1994b, 334; Szymczak 2004, 80, 104, 185; Stępiński et al. 2013, 172; Żabiński 2014, 123, 130.

<sup>112</sup> MTB, p. 140; Rathgen 1922, 23; Rathgen 1928, 404; Żabiński 2014, 123.

<sup>113</sup> MTB, p. 201; Engel 1897-1899, 230; Rathgen 1922, 24; Rathgen 1928, 404; Schmidtchen 1977a, 55; Świętosławski 1993, 21; Stępiński et al. 2013, 173; Żabiński 2014, 123.

<sup>114</sup> MTB, p. 217; Engel 1897-1899, 230; Rathgen 1922, 24; Rathgen 1928, 404; Schmidtchen 1977a, 55-56; Świętosławski 1993, 22; Szymczak 2004, 107; Stępiński et al. 2013, 173; Strzyż 2014, 101; Żabiński 2014, 121, 123, 128, 130.

<sup>115</sup> MTB, p. 309; Schmidtchen 1977a, 63; Świętosławski 1993, 22; Nowakowski 1994b, 335; Szymczak 2004, 107, 286; Józwiak and Trupinda 2007, 433; Klimek et al. 2013, 93; Stępiński et al. 2013, 172; Żabiński 2014, 130.

<sup>116</sup> MTB, p. 339; Engel 1897-1899, 230; Rathgen 1922, 25, 42; Rathgen 1928, 404; Schmidtchen 1977a, 63; Świętosławski 1993, 21; Nowakowski 1994a, 102; Stępiński et al. 2013, 173; Żabiński 2014, 123.

<sup>117</sup> NKRSME 1, p. 67; Żabiński 2014, 125.

<sup>118</sup> MTB, p. 479-480, 483, 496, 500-502, 505-506, 510-511, 524-525, 558; Engel 1897-1899, 230; Rathgen 1922, 25-27, 37-38; Rathgen 1928, 405, 411-412; Schmidtchen 1977a, 56-59, 64; Nowakowski 1994b, 334; Szymczak 2004, 108; Stępiński et al. 2013, 166-167, 173; Strzyż 2014, 108; Żabiński 2012, passim; Żabiński 2014, 121, 123.

<sup>119</sup> MTB, p. 502; Engel 1897-1899, 230; Rathgen 1922, 27; Rathgen 1928, 405, 409; Schmidtchen 1977a, 62; Świętosławski 1993, 22; Szymczak 2004, 80, 105; Józwiak and Trupinda 2007, 433; Stępiński et al. 2013, 172-173; Żabiński 2014, 130.

<sup>120</sup> MTB, p. 511; Engel 1897-1899, 231; Rathgen 1922, 29, 40; Rathgen 1928, 405; Schmidtchen 1977a, 58; Świętosławski 1993, 22; Szymczak 2004, 109; Dąbrowska 2009, 39; Stępiński et al. 2013, 173; Żabiński 2014, 128, 130.

- of the gun was 11.5 Zentners<sup>121</sup>. It was obviously a stone cannonball gun
- payment of 9 Marks to Heinrich Dumechen for two small stone cannonball *veuglaires* in 1409 (*cleyne steynbochsen, ycliche von 2 stocken, eyne geschruwete mit eyne polvergehuse, dy ander nicht geschruwet mit 3 polferhusen*)<sup>122</sup>. The person of Heinrich Dumechen obviously evidences that these guns were cast. There is also a later record from 1409 which mentions that Dumechen received 1 Zentner of tin (*zeen*) for 1 new gun consisting of two parts (*zur nuwen bochsen von 2 stocken*)<sup>123</sup>. It can be therefore assumed that at least one of these *veuglaires* was cast from bronze
  - payment of 22 Marks to Heinrich Dumechen the bell-founder (*glockengisser*) for 2 medium-sized guns (*mittelbochsen*) in 1409. These guns were cast from the Order's copper<sup>124</sup>. These were evidently stone cannonball guns
  - series of expenses for casting of a gun referred to as *bochse nest der grosen* (the second largest gun) at the Order's capital castle in 1409. Raw materials includes copper (*kopper*) and tin (*zen*)<sup>125</sup>. This cannon is believed to have been lent by Grand Master Heinrich von Plauen to Friedrich Burggrave of Nürnberg, the administrator of the Mark of Brandenburg in 1413<sup>126</sup>
  - series of expenses for casting of another long gun (*lange bochse*) at the castle of Marienburg (Malbork) in 1409. Among raw materials there were copper (*kopper*) and tin (*zeen*)<sup>127</sup>
  - payment for an unspecified number of stone cannonball guns (*stenbussen*) and 3 lead bullet guns (*lotbussen*) by the authorities of the Old Town of Elbing (Elbląg) in 1410. As the money was received by a bell-founder (*klockengeter*), one can naturally assume that these guns were cast from copper or its alloy<sup>128</sup>
  - casting of an unspecified number of guns (*bussen*) in the Old Town of Elbing (Elbląg) in 1410, with a mention of the use of copper<sup>129</sup>
  - payment for 5 guns (*bussen*) to master Hermann from Heilsberg (Lidzbark Warmiński), a bell-founder, which implies that these guns were made from copper or its alloy. The record states a total weight of 5.5 Zentners and 15 pounds for these guns<sup>130</sup>. If one assumes an equal weight of all the guns (over 50 kg each), one could suppose that they probably were light stone cannonball guns
  - casting of an unspecified number of guns (*bochsen*) at the castle of Marienburg (Malbork) in 1411, 1412, 1413, 1414, 1417, 1419 (with a mention of the use of copper) and 1420 (with a mention of the use of copper)<sup>131</sup>
  - purchase of 3 barrels of osemund iron (*vas ozemunt*) in 1411, which was supposed to be used for forging guns at the castle of Marienburg (Malbork)<sup>132</sup>
  - casting of a large cannon (*grosse buchse*, a stone cannonball gun) in the Old Town of Elbing (Elbląg) in 1411. Furthermore, the same founder cast 14 lead bullet guns<sup>133</sup>
  - casting of a large long cannon (*grosse lange buchse*, so evidently a stone cannonball gun) at the castle of Marienburg (Malbork) in 1413<sup>134</sup>
  - mention of spending of 34 Marks 22 Scots in food, copper, tin and cash for the manufacture of a gun (*buchsse*) in the Old Town of Elbing (Elbląg) in 1414<sup>135</sup>. The sum itself implies that it was a stone cannonball gun
  - mention of spending 78 Marks for 1 gun (*buchse*) bought by the Old Town of Elbing (Elbląg) from the City of Gdańsk (Danzig) in 1414<sup>136</sup>. The weight of the gun (12.5 Zentners) clearly points to a stone cannonball gun and the price strongly suggests copper or copper alloy
  - purchase of 7 stone cannonball guns (*steinbuchsen*), 10 large lead bullet guns (*grose lotbuchsen*) and 13 small lead bullet guns (*cleine lotbuchsen*) by the authorities of the Old Town of Elbing (Elbląg) in 1414. Their total price was 69 Marks 8 Scots and 9 Denars and their total weight was 12.5 Zentner and 13 pounds, which gives about 5.5 Marks

<sup>121</sup> MTB, p. 554, 558-559; Engel 1897-1899, 231; Rathgen 1922, 29-30, 40; Rathgen 1928, 407, 413; Schmidtchen 1977a, 61-62; Świętosławski 1993, 23; Szymczak 2004, 107, 109-110; Strzyż 2011, 33; Stepiński et al. 2013, 183; Strzyż 2014, 101; Żabiński 2014, 123-124, 131.

<sup>122</sup> MTB, p. 558; Engel 1897-1899, 231; Górski 1902, 26; Rathgen 1922, 29, 47-48; Rathgen 1928, 406; Schmidtchen 1977a, 60; Świętosławski 1993, 22; Szymczak 1998, 284; Szymczak 2004, 56-57, 107; Stepiński et al. 2013, 173.

<sup>123</sup> MTB, p. 591; Rathgen 1922, 33; Rathgen 1928, 408.

<sup>124</sup> MTB, p. 558; Engel 1897-1899, 231; Rathgen 1922, 29, 40; Rathgen 1928, 407, 413; Schmidtchen 1977a, 60; Świętosławski 1993, 22; Stepiński et al. 2013, 173.

<sup>125</sup> MTB, p. 557-558; Engel 1897-1899, 231; Żabiński 2014, 121-123, 130.

<sup>126</sup> Rathgen 1922, 28-29, 40; Rathgen 1924, passim; Rathgen 1928, 406, 413; Müller 1968b, 29; Goetz 1985, 48; Żabiński 2012, 32.

<sup>127</sup> MTB, p. 590-591; Rathgen 1922, 33, 40; Rathgen 1928, 408; Żabiński 2014, 122, 131.

<sup>128</sup> NKRSME 1, p. 217; Rathgen 1922, 67; Rathgen 1928, 427; Chodyński 1996a, 17; Szymczak 2004, 186; Stepiński et al. 2013, 133; Żabiński 2014, 133.

<sup>129</sup> NKRSME 1, p. 229; Rathgen 1922, 67; Rathgen 1928, 427; Świętosławski 1993, 21; Szymczak 2004, 109; Żabiński 2014, 133.

<sup>130</sup> NKRSME 1, p. 229, EK, p. 242; Rathgen 1922, 68, 74; Rathgen 1928, 427, 430; Świętosławski 1993, 21; Szymczak 2004, 109, 186; Stepiński et al. 2013, 183.

<sup>131</sup> ABMH, p. 25, 27-28, 46, 61-62, 104, 126, 252, 334, 354, 357-359; Żabiński 2014, 131.

<sup>132</sup> MKB, p. 252; Klimek et al. 2013, 93; Żabiński 2014, 122.

<sup>133</sup> NKRSME 2, p. 10; EK, p. 252; Rathgen 1922, 70, 74-75; Rathgen 1928, 428; Świętosławski 1993, 21; Szymczak 2004, 109; Stepiński et al. 2013, 183; Żabiński 2014, 125.

<sup>134</sup> ABMH, p. 104-105; Żabiński 2014, 124.

<sup>135</sup> NKRSME 2, p. 77.

<sup>136</sup> NKRSME 2, p. 78; Rathgen 1922, 70, 75-76; Rathgen 1928, 428, 430-431; Świętosławski 1993, 21; Szymczak 2004, 109; Żabiński 2014, 122.

<b>Artillery guns – 41 (100%)</b> iron – 3 (7.32%) bronze – 19 (46.34%) <sup>a</sup> copper – 3 (7.32%) unspecified Cu alloy – 16 (39.02%) <sup>b</sup> total Cu and its alloys – 38 (92.68%)	<b>Hand-held guns, very light cannons – 62 (100%)</b> iron – 18 (29.03%) bronze – copper – 4 (6.45%) unspecified Cu alloy – 40 (64.523%) total Cu and its alloys – 44 (70.97%)
<sup>a</sup> including the Order's 1 <i>grose bochse</i> , 1 <i>cleyne lange bochse</i> , 1 <i>bochse nest der grosen</i> , and 1 <i>lange bochse</i> <sup>b</sup> including 1 <i>grose bochse</i> of Elbing (Elbląg), 1 <i>grose lange bochse</i> of the Order, 1 large gun bought by Elbing (Elbląg) in Gdańsk (Danzig)	
<b>Total all: 103 (100%)</b> Total iron: 21 (20.39%) Total bronze: 19 (18.45%) Total copper: 7 (6.80%) Total unspecified Cu alloy: 56 (54.37%)	
Total Cu and its alloys: 82 (79.61%) Sources: MTB 119-120, 140, 201, 217, 309, 339, 479-480, 483, 496, 500-502, 505-506, 510-511, 524-525, 554, 557-559, 590-591; NKRSME 1, 217, 229; NKRSME 2, 10, 77-79; ABMH 104-105, 176; EK 242, 252; KKMT, No. 15.	

Tab. 2. Raw materials in guns in the Teutonic Order's state (after 1400-mid-15<sup>th</sup> c.) according to account books. Author: G. Żabiński.

per Zentner<sup>137</sup>. This strongly implies the use of copper or its alloy, as in the previous case

- mention of a purchase of stone cannonballs (*steine*) for an iron gun (*czu der iseren buchsen*) by the authorities of the Old Town of Elbing (Elbląg) in 1414<sup>138</sup>
- casting of 1 unspecified gun (*bochse*) at the castle of Marienburg (Malbork) in 1415, with a mention of 17 men operating bellows<sup>139</sup>. This strongly suggests a considerable size of the gun, which therefore was in all probability a stone cannonball one.
- 6 iron veuglaires (*eysern camerbuchssen*) were bought in 1461 by the authorities of Toruń (Thorn) from a woman called Pfeilschestynne<sup>140</sup>

Pieces of information from account books seem to confirm observations which were made based on inventories and reports (Tab 2). A preponderance of copper alloys is even more evident. This is especially clear in the case of artillery. Within this group, it is also notable that bronze seems to have been the most preferred. Interestingly, almost all the heaviest guns of the Order were cast from bronze. This demonstrates that bronze was considered the most reliable metal for cannons exposed to especially heavy stress<sup>141</sup>. This observation is even more significant due to the fact that numerous surviving examples of European heavy cannons from the period in question were assembled from iron bars and rims. One can mention here the following guns: the *Faule Magd* (early 15<sup>th</sup> c., about 1320 kg) from the Royal Arsenal in Dresden<sup>142</sup>; two English *Michelettes*

from Mont St. Michel (before 1423, 3250 and 5385 kg)<sup>143</sup>; the *Pumhart von Steyr* (c. 1425) from Vienna<sup>144</sup>; the *Dulle Griet* (after 1430, 16400 kg) from Ghent<sup>145</sup>; a Burgundian bombard from the Historisches Museum in Basel in Switzerland (c. 1450)<sup>146</sup>; the *Mons Meg* from Edinburgh (1449, 6040 kg)<sup>147</sup>; a bombard from Basel (2000 kg)<sup>148</sup>. Concerning the largest bronze cannons, the following examples stand out: the *Große Frankfurter Buchse* of Tannenberg (1394, 3500 kg)<sup>149</sup>; the Austrian *Katharina* (1404, 4597 kg)<sup>150</sup>; the *Faule Grete* (4600 kg, possibly identical with the Teutonic *Bochse nest der grosten* from 1409)<sup>151</sup>; the *Häre* from Basel (c. 1411, 4600 kg)<sup>152</sup>; the *Faule Mette* from Braunschweig (1411, 8228 or 8730-8750 kg)<sup>153</sup>; the *Unverzagt* of

<sup>143</sup> Rathgen 1928, 514-517; Goetz 1985, 48; Smith and Brown 1989, 68-78, Figs. 51-60; Strzyż 2011, 79-80, Tab. 1; Strzyż 2014, 233.

<sup>144</sup> Rathgen 1928, 230-231; Goetz 1985, 37, 48.

<sup>145</sup> Rathgen 1928, 514-515; 517-518; Müller 1968b, 28; Goetz 1985, 26, 48; Smith and Brown 1989, 23-28, Figs. 15-24; Szymczak 2004, 63, 76, Tab. 2; Smith and DeVries 2005, 204, 266-267; Strzyż 2011, 79-80, Tab. 1; Strzyż 2014, 105-106, 232-233.

<sup>146</sup> Smith and Brown 1989, 39-45, Figs. 25-31; Smith and DeVries 2005, 264-265, cat. No. 2; Strzyż 2011, 79-80, Tab. 1; Strzyż 2014, 233.

<sup>147</sup> Rathgen 1928, 514-515, 518; Goetz 1985, 48; Smith and Brown 1989, 1-21, Figs. 3-14; Smith 2000, 74-76; Szymczak 2004, 76, Tab. 2; Smith and DeVries 2005, 204, 262-263, cat. No. 1; Strzyż 2011, 79-80, Tab. 1; Strzyż 2014, 105, 233.

<sup>148</sup> Rathgen 1928, 230-232, 514-515.

<sup>149</sup> Rathgen 1928, 33-36; Müller 1968b, 29, 36, Fig. 14; Goetz 1985, 48, 51; Szymczak 2004, 76, Tab. 2; Strzyż 2011, 81, Tab. 2.

<sup>150</sup> Goetz 1985, 48.

<sup>151</sup> Rathgen 1924, passim; Rathgen 1928, 459-476; Müller 1968b, 29; Goetz 1985, 48; Szymczak 2004, 76, Tab. 2; Żabiński 2012, 32.

<sup>152</sup> Rathgen 1928, 481; Goetz 1985, 48.

<sup>153</sup> Rathgen 1928, 274-280, 524; Müller 1968b, 28, 36, Fig. 15; Goetz 1985, 48; Strzyż 2011, 81, Tab. 2.

<sup>137</sup> NKRSME 2, p. 78; Rathgen 1922, 70; Rathgen 1928, 428.

<sup>138</sup> NKRSME 2, p. 79; Rathgen 1922, 71; Rathgen 1928, 429.

<sup>139</sup> ABMH, p. 176; Żabiński 2014, 130.

<sup>140</sup> KKMT, No. 15; Klimek et al. 2013, 93; Żabiński 2014, 122.

<sup>141</sup> See also Rathgen 1922, 34-35; Rathgen 1928, 119.

<sup>142</sup> Baermann 1906-1908, 229-235; Rathgen 1928, 230-232; Goetz 1985, 26, 48; Strzyż 2011, 79-80, Tab. 1; Strzyż 2014, 106, 233.

Köln (1416, perhaps c. 7500 kg)<sup>154</sup>; a Turkish cannon, the so-called Bombard of Muhammad in the collection of the Tower of London (1464, 17500 kg)<sup>155</sup>; the “Swine” (*Sau*) from Świdnica (Schweidnitz) in Silesia (1467, 8500 kg)<sup>156</sup>. For the group of hand-held firearms or very light cannons, similar conclusions can be drawn. On the other hand, the role of iron was clearly higher in this group.

What is clearly different in both groups of sources is the significance of guns which were referred to as made from “pure” copper. Inventories and visitation reports mention 67 such guns altogether (24.45% of all guns, excluding the 111 brass hand-held guns from c. 1523), including 30 artillery pieces (35.29% of all such guns), 33 hand-held guns or very light cannons (22.60% of all such guns, excluding brass hand-held guns), and 4 unspecified guns (9.30% of all such guns). On the other hand, account books report on merely 7 such guns altogether (6.80% of all guns), including 3 artillery pieces (7.32% of all such guns) and 4 hand-held guns or very light cannons (6.45% of all such guns). It could be tentatively proposed that some guns may have been erroneously classified by authors of inventories and visitation reports, i.e., some copper alloy guns were mistaken for copper guns and *vice versa*.

With regard to metal projectiles, the most commonly used term is *gelote* or *gelothe*, which is plural from *lot* (*loth* – a piece of lead, weight, a firearms projectile, a lead plummet in a plumb, etc.). It may also stand for an alloy of tin and lead to solder (*löthen*) things together. In this sense it can also be used for alloys of other metals or, e.g., weights made from iron (see *loth*, *löthen* and *gelöthe*, *Deutsches Wörterbuch von Jacob Grimm und Wilhelm Grimm*, <http://woerterbuchnetz.de/DWB/>). It is therefore not surprising that in most cases *gelote* were in all probability lead bullets. Records of *gelote* are far too numerous in sources to deal with individually. Therefore, only such cases will be mentioned if stores of projectiles were also accompanied with stores of lead, if it was clearly stated that lead was used or was supposed to be used for projectiles, or if stores of lead were recorded as part of weaponry resources:

- 2.5 Zentners of lead for bullets (*bley czu gelothem*) in the Commandery of Radzyń Chełmiński (Rehden) in 1411 and 1412<sup>157</sup>
- 0.5 Zentner of lead for bullets (*bly czu gelote*) in the Commandery of Toruń (Thorn) in 1413<sup>158</sup>
- 4 Zentners of non-cast lead (*ungegossens blyes*) and 540 bullets (*gelote*) in the Commandery of Człuchów (Schlochau) in 1413<sup>159</sup>

- 1 Zentner of lead (*blye*), 240 bullets (*gelote*) and 480 pieces (possibly of lead) for bullets (*stucke czu gelothe*) in the Commandery of Memel (Klaipeda) in 1414. In 1416, 3 stones of lead (*bley*) and 90 bullets (*gelote*) were recorded there<sup>160</sup>
- 2640 bullets (*gelote*) and 2 Zentners of lead (*blye*) in the Commandery of Brodnica (Strassburg) in 1414. In 1415, 1417, and 1419, 115 stones of lead (*blies*) were recorded there. The records from 1415 and 1419 were provided with a mention that this figure also encompassed 1440 bullets (*gelote*)<sup>161</sup>
- 600 bullets (*gelote*) and 1 Zentner of lead (*bley*) in the Reeveship of Lipienek (Leipe)<sup>162</sup> in 1416
- an unspecified number of bullets (*lote*) and 3 Zentners of lead (*bley*) in the Commandery of Tuchola (Tuchel) in 1417<sup>163</sup>. In 1422 the inventory mentioned 1140 bullets (*gelote*) and 1 Zentner of non-cast lead (*blyes ungegossen*). In 1431 there were 0.5 Zentner of lead (*bley*) and 780 bullets of various size (*gelote cleyn und gros*). Only lead was mentioned in 1437, while a year later the inventory also recorded 7800 bullets of various size<sup>164</sup>
- 200 bullets (*gelote*) and 1 Zentner of lead (*bley*) in the Commandery of Papowo (Papau) in 1419 and 1421<sup>165</sup>. 360 bullets and the same amount of lead were recorded in another inventory for Papowo (Papau), which is generally dated to the period before 1454<sup>166</sup>
- 3 Zentners of lead (*bley*) in the Reeveship of Tczew (Dirschau) in 1422<sup>167</sup>
- 5 Zentners of lead (*bleyes*) in the Commandery of Gniew (Mewe) in 1431<sup>168</sup>
- 1 Zentner of lead with bullets (*bly mit den geloten*) in the Procurator’s Office in Neidenburg (Nidzica) in the Commandery of Osterode (Ostróda) in 1437. In 1438 the inventory recorded the same amount of lead and 240 bullets (*gelote*)<sup>169</sup>. A visitation report from 1446 recorded 1 Zentner of lead with “other bullets” (*mit andern geloten*)<sup>170</sup>. The same was repeated in 1449<sup>171</sup>, while 2.5 Zentners of lead were mentioned in 1507 and 1508<sup>172</sup>
- 20 lead bullets (*bleyen gelothe*) were sent in June 1455 from Toruń (Thorn) to the troops of the Prussian Confederacy operating in Lower Prussia<sup>173</sup>

<sup>154</sup> Rathgen 1928, 308-314.

<sup>155</sup> Rathgen 1928, 524; Williams and Paterson 1986, 186.

<sup>156</sup> Szymczak 2004, 76, Tab. 2.

<sup>157</sup> GÄDO, p. 565, 567; Rathgen 1922, 17; Żabiński 2014, 127.

<sup>158</sup> GÄDO, p. 434; Nowakowski 2004, 227.

<sup>159</sup> GÄDO, p. 652; Żabiński 2014, 127.

<sup>160</sup> GÄDO, p. 305-306; Żabiński 2014, 127.

<sup>161</sup> GÄDO, p. 383-387; Rathgen 1922, 10-11; Rathgen 1928, 396; Żabiński 2014, 127.

<sup>162</sup> GÄDO, p. 533; Żabiński 2014, 127.

<sup>163</sup> GÄDO, p. 638; Rathgen 1922, 18.

<sup>164</sup> GÄDO, p. 642-645; Żabiński 2014, 127.

<sup>165</sup> GÄDO, p. 519-520.

<sup>166</sup> GÄDO, p. 523; Żabiński 2014, 127.

<sup>167</sup> GÄDO, p. 726; Żabiński 2014, 127.

<sup>168</sup> GÄDO, p. 748; Żabiński 2014, 127.

<sup>169</sup> GÄDO, p. 353-354.

<sup>170</sup> GÄDO, p. 355; Visitationen 1, No. 123, p. 262-263.

<sup>171</sup> GÄDO, p. 339.

<sup>172</sup> GÄDO, p. 358-359; Żabiński 2014, 127.

<sup>173</sup> Biskup 1966, 88.

- 5.5 stones of lead (*bley*) were sent from Toruń (Thorn) to Radzyń (Rehden) and 2 lispounds of lead to Gardeja (Garnsee) in early 1456 to support the troops of the Prussian Confederacy. There are also analogous records from 1457, 1460, and 1461<sup>174</sup>
- 1 Zentner of lead (*blei*) in the Procurator's Office of Ortelburg (Szczytno) in 1507 and 1508<sup>175</sup>. In 1521, 2 Zentners were recorded<sup>176</sup>
- some three-scores of lead bullets (*etlich schok bleien glott*) in the Procurator's Office in Preussisch Mark (Przezmark) in 1507<sup>177</sup>
- 4 Zentners of lead (*blei*) and 350 bullets (*glotte*) in the Commandery of Rhein (Ryn) in 1507 and 1508<sup>178</sup>
- 1 Zentner of lead (*blei*) in the Commandery of Osterode (Ostróda) in 1507 and 1508<sup>179</sup>
- some tablets of lead (*etliche tauffel bley*) at the castle of Mohrungen (Morąg) in 1518<sup>180</sup>
- 5 stones of lead (*bley*) in the Procurator's Office in Lochstedt (Pavlovo) in 1511-1521<sup>181</sup>
- 1 Zentner of lead (*pley*) in the Procurator's Office in Insterburg (Černyahovsk) in 1511-1521<sup>182</sup>

However, iron was also explicitly mentioned as the raw material for projectiles called *gelote*. 120 *yserinne gelote* were recorded in the Reeveship of Brattian (Bratian) in 1411<sup>183</sup>.

Another kind of metal projectiles were shots, referred to as *schrotten*:

- 1 large trough with iron shots (*grosse mulde mit eisern schrotten*) and 1 chest with large and small iron shots (*kastern mit eisern schrotten klein und gros*) in the Procurator's Office in Preussisch Mark (Przezmark) in 1507. Interestingly, another inventory from 1507 mentioned 1 chest with large and small bullets (*kasten mit glotten klein und gros*)<sup>184</sup>. If both mentions referred to the same chest, it could be another premise that the term *gelot* was also used for iron projectiles. On the other hand, as the other inventory did not separately mention three-scores of lead bullets, it is also possible that in the meantime all iron shots were packed into one chest and the other one was used to store lead bullets.

- numerous shots (*notdurfft schrott*) in the Commandery of Rhein (Ryn) in 1507 and 1508<sup>185</sup>

Late Teutonic sources also inform on iron projectiles which were undoubtedly cannonballs:

- the anonymous inventory of stores of firearms of the Teutonic Order from c. 1523 mentions numerous firearms (both artillery and hand-held guns) in Tapiaw (Gvardeysk). It also states that there are 2210 iron projectiles (*eyssernkugeln*) to these guns. Furthermore, 3450 *eysenn kugeln* were recorded in Preussisch Mark (Przezmark)<sup>186</sup>

Metal projectiles for firearms are also frequently mentioned in account books from the territory of the Teutonic Order's state. Analogously to data from inventories and reports, only such mentions which allow for an identification of raw materials will be discussed here:

- 25 stones of lead for bullets (*steyne blyes zu geloten*) were sent in 1401 to the castle of Gotteswerder (Raudondvaris on the River Neman near Kaunas). Among expenses on this castle, there was also money paid for making 12500 bullets (*gelote*) and shots (*hailgeschis*)<sup>187</sup>
- 2 stones and 6 pounds of lead (*blyges*) were paid for by the authorities of the Old Town of Elbing (Elbląg) in 1404. This expenditure was listed together with expenses for a lead bullet gun and linstocks<sup>188</sup>
- 1 Mark was paid for casting of 6 Zentners of lead bullets (*blyinnen gelote zu gissen*) at the castle of Marienburg (Malbork) in 1408<sup>189</sup>
- 2 Zentners of lead (*bly*) were bought in 1409 for making bullets (*geloten*), which were to be sent to Ragnit (Neman)<sup>190</sup>
- 16 Scots were spend by the House Commander of Toruń (Thorn) for 0.5 Zentner of lead for bullets (*bly zu geloten*)<sup>191</sup>
- 2 Marks were paid by the town council of Toruń (Thorn) for lead for bullets (*bley czu gloten*) in 1459. These bullets were to be used by the troops of the Prussian Confederacy<sup>192</sup>

<sup>174</sup> Biskup 1966, 87-89, 92-93; Biskup 1967, 574, 586.

<sup>175</sup> GÄDO, p. 118, 120.

<sup>176</sup> GÄDO, p. 123.

<sup>177</sup> GÄDO, p. 147.

<sup>178</sup> GÄDO, p. 199-200.

<sup>179</sup> GÄDO, p. 344-345.

<sup>180</sup> GÄDO, p. 113-115.

<sup>181</sup> GÄDO, p. 53.

<sup>182</sup> GÄDO, p. 66.

<sup>183</sup> GÄDO, p. 366; Rathgen 1922, 16, 81; Rathgen 1928, 400; Stepiński et al. 2013, 179; cf. Rathgen 1928, 329, 333, 363, 451, 454.

<sup>184</sup> GÄDO, p. 147-148.

<sup>185</sup> GÄDO, p. 199-200.

<sup>186</sup> Biskup 1984, 102.

<sup>187</sup> MTB, p. 116, 127; Engel 1897-1899, 232; Rathgen 1922, 23; Rathgen 1928, 404, 436; Dąbrowska 2009, 40; Stepiński et al. 2013, 174; Żabiński 2014, 126.

<sup>188</sup> NKRSME 1, 16; Rathgen 1922, 67; Rathgen 1928, 427; Żabiński 2014, 127.

<sup>189</sup> MTB, p. 511; Rathgen 1922, 27; Rathgen 1928, 405; Dąbrowska 2009, 40.

<sup>190</sup> MTB, p. 559; Żabiński 2014, 126.

<sup>191</sup> MTB, p. 596; Rathgen 1922, 33; Rathgen 1928, 408.

<sup>192</sup> KT, p. 102; KŻZZP, p. 102.

Mentions of raw materials other than lead include:

- payment for 17 stones of shots, including raw material (iron) and labour costs (*hagelgeschos vor ysen und machelon*), to be sent to Memel (Klaipėda) in 1403<sup>193</sup>
- purchase of 2 skippounds of iron (*ysens*) for the smithing master (*smedemeyster*) at the castle of Marienburg (Malbork) for casting large projectiles for terrace guns (*in dy grosen gelote czu gissen czu den tarrasbochsen*) in 1412<sup>194</sup>. This record is of great significance, as it informs that the Order's specialists mastered necessary skills to use cast iron

Eventually, some interesting pieces of information on projectiles can also be found in narrative sources:

- firing of 800 iron projectiles (*eiserne gelude*) by the troops of the Grand Master besieging Heilsberg (Lidzbark Warmiński) in Autumn 1520 was mentioned in the *Ferber-Chronik*. As the chronicle recorded the presence of heavy artillery (*grossen schweren buxen*), it can be assumed that these projectiles were iron cannonballs<sup>195</sup>. The use of *eisern kaulen* is also mentioned by Grunau<sup>196</sup>.
- iron projectiles (*eisener gelot adir kolben*) for artillery in the early 16<sup>th</sup> c. are mentioned in the chronicle of Simon Grunau<sup>197</sup>. Furthermore, this author also recorded the support given by Hiob von Dobeneck Bishop of Pomesania to Grand Master Albrecht von Hohenzollern (1511-1525) in his preparations for war against Poland. Bishop Hiob was said to import Swedish iron (*Swedisch eysen*) from Gdańsk (Danzig) in order to make iron projectiles (*eyserne kaulen zcu den buchxen*). These were then taken by the Grand Master<sup>198</sup>. Grunau also offered a rather bizarre description of cannonballs used by the Polish troops in the siege of Kwidzyn (Marienwerder) in early 1520. He said that 4 Polish cannons launched stone cannonballs or balls, each weighing 3.5 Zentners of iron (*steine oder kaulen, ein igliche von 3.5 centtener eisen*)<sup>199</sup>
- among military supplies sent by the Grand Master to the King of Denmark in 1522 there were also cannonballs, cut from stone or cast from iron, bronze (?) and lead (*kaulen, von stein gehauen, von eisen, ertz und blei gegossen*)<sup>200</sup>

Based on this data, it can be said that in the light of written sources most metal projectiles were made from lead, while iron bullets or shots are mentioned rather sporadically. On the other hand, of utmost interest is a quite early mention of the use of cast iron projectiles for artillery (terrace guns in this case, in all probability some sort of light cannons) in 1412. However, large calibre iron cannonballs appear on a large scale only after c. 1470 in Europe<sup>201</sup>.

#### Technology of gun barrel manufacture – general data

As it is known, early firearms were made from two raw materials, that is, iron and copper and its alloys. This implied the use of two basic techniques of manufacture. In the case of iron, it was forging of rods and rims or hoops and then assembling them into the shape of the barrel. This technique was especially preferred for very heavy guns. In the case of light artillery or hand-held firearms, the entire barrel could be forged from one or several pieces of iron. Cast iron became available in Europe on a wider scale with the introduction of the blast furnace and refining process, which first took place in the late 12<sup>th</sup> c. in the regions of Sauerland and Siegerland in Germany, in northern Italy, as well as in Sweden<sup>202</sup>. Perhaps as early as the late 14<sup>th</sup> c. in Western Europe some isolated attempts at casting of iron guns were also undertaken. Cast iron guns were much cheaper than those from copper alloys (perhaps even 6-12 times), but due to their brittleness they could be much less reliable and much more dangerous for artillerymen<sup>203</sup>. Casting was used for copper and its alloys. A clay

<sup>201</sup> See., e.g., Górski 1902, 33; Rathgen 1928, 120; Fino 1974, 25; Mielczarek 1998b, 71; Szymczak 2004, 15-16, 82, 152, 281; Strzyż 2011, 71-73; Strzyż 2014, 122, 132; for finds of cast iron projectiles for both hand-held guns and artillery see, e.g., Chudzińska 2011, 205, 207-208, Figs. 3.1-3, 211; Strzyż 2011, 52-53, 72, Tab. 2, 128, cat. No. 13, 130, cat. Nos. 32-34, Figs. XLIII.4, Tab. 2, 169, cat. No. 640, Fig. XLI.6, 174, cat. No. 799, XLI.5; Strzyż 2014, 122, 132, cat. No. 97, cat. No. 130, Fig. CVI-II.1, cat. No. 211, cat. No. 213, Fig. CI.4, cat. No. 215, Fig. CI.6, cat. No. 359, Fig. CVII.15, cat. No. 360, Fig. CVII.7, cat. No. 712, Fig. CVII.6, cat. No. 1016, CVIII.3.

<sup>202</sup> Buchwald 2005, 337-340; Buchwald 2008, 185-187, 204-209, 226-232, 240-250, 268, 302-310.

<sup>203</sup> see, e.g., Górski 1902, 28, 31; Johanssen 1918, 1-20; Rathgen 1922, 9-12, 34, 81; Rathgen 1928, 27-29; Müller 1968a, 14-15; Fino 1974, 18; Schmidtchen 1977b, 14, 20, 49; Goetz 1985, 26, 48; Smith and Brown 1989, 1-3, 11, 13, 23, 25, 28, 42-43, 46-50, 52-78; Głosek 1990, 156-158; Mielczarek 1998a, 62; Smith and DeVries 2005, 240, 262-263, cat. No. 1, 264-265, cat. No. 2, 266-267, cat. No. 3; Smith 2000, passim; Szymczak 2004, 80-83; Buchwald 2008, 323-330; Williams 2012, 192-195; Klimek et al. 2013, 83-85; Strzyż 2011, 19, 23-25, 28, 30-31, 40-48, 80-81, catalogue: Tab. 1, 123-125, cat. Nos. 1, 2, 10, 11, 13, 14, 15, Figs. V.1-6, VII.2-6, VIII.1-7, Tab. 1A, 126-127, cat. Nos. 1A-7A, Figs. XII.1-3, XIII.1-3, XIV.1-2, XV.1-3, XVI.1-3, XVII.1-6; Strzyż 2014, 105-106, 232-238, catalogue, cat. Nos. 1, 2, 4-11, 13, 16, 17, 19, 20-44, 47-51, 53-55, 57-72, 74-76, 79, 80, 87-89, 92, 99, 100, 103-111, 115, 122, 125-128, 134-157, 160-166, 168-169, 171-185, 187, 189-190, 192.

<sup>193</sup> MTB, p. 248; Engel 1897-1899, 232; Rathgen 1922, 24; Rathgen 1928, 404; Świętosławski 1993, 25; Żabiński 2014, 126.

<sup>194</sup> MKB, p. 282; Rathgen 1922, 78-80 and Rathgen 1928, 433-434 – this scholar assumes that this record concerns lead projectiles cast over an iron core; for such projectiles see also Klimek et al. 2013, 93; Strzyż 2014, 111, 113, 115, 118, 120; Żabiński 2014, 122, 134.

<sup>195</sup> *Ferber-Chronik*, p. 533.

<sup>196</sup> *Preussische Chronik* 2, p. 551-552.

<sup>197</sup> *Preussische Chronik* 1, p. 48.

<sup>198</sup> *Preussische Chronik* 1, p. 322-323.

<sup>199</sup> *Preussische Chronik* 2, p. 522-523; Biskup 1993, 278.

<sup>200</sup> *Preussische Chronik* 2, p. 654.

model of the barrel (a so-called false or counterfeit model) was made first. Then, a mould was made around it. After firing the mould, the false model was removed and an iron rod wrapped with a rope (a core) was fixed inside the mould. After casting, the core was removed and the barrel was bored in order to receive a bore with required calibre. It could also be supposed that a technique of lost-wax (*cire-perdue*) may have been used for lighter cannons and hand-held firearms. In this case, one first prepared the core (which fulfilled the role of the false model). It consisted of a wooden shaft, wrapped with ropes and covered with clay. Its surface was covered with wax and tallow. Alternatively, the entire model could be made from wax. After preparing the clay mould around the core, the mould was fired and the wax melted away. Further procedures in this technique were analogous to the previous one. Hand-held firearms were also cast using wooden patterns, which were covered with tallow or wax and then with clay in order to receive a mould<sup>204</sup>. Worth mentioning is also the account of Kritoboulos from 1467 on casting of a breech of a large cannon by the Turks during the siege of Constantinople in 1453. In this description, a cylindrical core of clay and linen was made first. The next step was to make a mould (an "exterior shape") of the same materials. The mould accommodated the core and some empty space remained between the mould and the core, to receive the cast metal. The mould was additionally reinforced with iron, timber, earth and stones<sup>205</sup>. A very informative description of gun casting is offered in the work of an Italian metallurgist Vannoccio Biringuccio from 1540. The first step is to make a wooden or clay pattern, which should exactly represent the shape of the gun with its ornaments and rings. In case one makes the pattern from wood, the wooden beam should be longer than the gun itself, so that the pattern could be turned and so that it is possible to attach a feeding head on the mouth side. If the beam (which acts as a spindle) is not thick enough, it is pivoted on trestles and covered with a rope. Then, one applies coats of clay up to the desired thickness. Before the last or the last two coats of clay one should also apply a coat of ashes. The pattern is placed on two bearing trestles and cornice pieces are put at the mouth and at the foot of the

gun. Then, a clay or wooden wheel is made. It should be three *dita* thick and one or more *dita* larger than the diameter of the circumference of the cornice at the end of the gun. The role of this wheel will be to provide a junction with the breech, or to secure an enlargement into which the breech will fit. Next, a ball-shaped feeding head is made at the cornice at the mouth of the gun. The feeding head will be used for pouring of bronze into the mould. Above the feeding head one makes another wheel. Both wheels at both ends will be sockets – the former for the breech and the latter for the core. The core will fill the space for gunpowder and cannonball and it will be inserted into the mould when the pattern is removed. Therefore, both wheels should be applied with ashes or tallow, so that they stay in place when the spindle (the beam around which the pattern was made) is drawn out. The next step is to make trunnions. These are to be fastened with two long nails to the pattern, so that one can take them out after the mould has been made. The pattern is eventually covered with ashes and tallow or other fat. Then, the mould is to be made – the first coat of loam is applied on the pattern, and after the first one is dried by fire or sun, next layers of loam follow. The penultimate coat should be covered with a layer of iron wires two *dita* apart from each other. Another coat of clay is applied on the wire. After the mould dries, it is additionally reinforced with 6 to 8 iron rods equal in length to the mould and with iron bars at a distance of 1/3-1/2 ell from each other. This iron cage is covered with another coat of clay. After the mould dries, it is fired until the heat penetrates to the pattern and loosens the wax or tallow between the mould and the pattern. Then, the mould is lifted and one removes the nails holding the trunnions. In the next step, the spindle (the initial beam of wood) is removed from inside and the mould making the outside of the finished gun is empty and clean. Then, one makes the placing at the end of the gun, which will hold the core in the middle. The best way which is recommended by Biringuccio is a so-called collar. It is an iron ring with its diameter corresponding to the thickness of the core. This ring is provided with four legs arranged in the shape of the cross, which pass through the mould. The legs are fixed below the foot cornice with clay, iron wedges or chips of stone. Alternatively, one can use four pieces of iron with fork-shaped heads, which form a circular segment. Yet another way is to use a so-called castle. It consists of two pieces of iron forming a cross. They are bent in the middle and make a raised part, on which four pieces of iron resembling a small candelabra are riveted. When the irons are fixed where they should be, the inside of the mould is smeared with water or egg white mixed with ashes of a ram's horn in order to fill possible little pores. Then, the mould is left to dry<sup>206</sup>.

<sup>204</sup> See, e.g., Górski 1902, 28, 31, 41; Rathgen 1922, 9-12, 14, 34-39, 43-48; Rathgen 1928, passim; Müller 1968b, 21-32; Schmidtchen 1977a, passim; Schmidtchen 1977b, 14, 20, 52-53; Goetz 1985, 16, 26, 45-46; Głosek 1990, 156-158; Mielczarek 1998a, 62-63; Mielczarek 1998b, 67, 71; Klimek et al. 2013, 83; Szymczak 2004, 83-92; Dąbrowska 2009, 28-33; Strzyż 2011, 16-20, 22-23, 26-29, 33-36, 81, catalogue: Tab. 1, 123-126, cat. Nos. 3-9, 12, 16-18, Figs. I.1-4, II.1-3, III.1-3, IV.1-6, VI.1-8, VII.2-3, IX-X, XI.1; Żabiński 2012, 33-34; Stępiński et al. 2013, 185; Strzyż 2014, 214-232, catalogue, cat. Nos. 3, 12, 14, 15, 18, 45, 46, 52, 73, 77, 78, 81-86, 89-91, 93-98, 101, 102, 112-114, 116-121, 123, 124, 129, 130, 132, 133, 158, 159, 167, 170, 186, 188, 191, 193, 194.

<sup>205</sup> Williams and Paterson 1986, 186-187; Dąbrowska 2009, 28; Strzyż 2014, 216.

<sup>206</sup> Biringuccio, *The Pirotechnia*, Book VI, Chapter 5, p. 234-239.

The next chapter discusses the construction of the core. An iron spindle is provided with a perforated heel at its upper end, and at its lower end there should be a hole to accommodate the afore mentioned irons which fasten the core to the mound. The spindle is placed on two trestles and is covered with ashes and then wrapped with a rope in such a manner that a *dito* of iron in every *palmo* of length is uncovered. Alternatively, the spindle can be covered with hemp tow or with wash ashes or powdered charcoal mixed with clay water or egg white. Then, the spindle is covered with a coat of clay, mixed with cloth clippings, horse dung and clean ash. The coat is bound with hemp tow and is left to dry. New layers of coating are applied until the thickness of the core matches the diameter of the cannonball. A wooden board is fastened on the trestles at a distance of the required thickness of clay. The spindle is turned and more clay is applied on it until the thickness of clay reaches the edge of the board. After finishing works the core is left to dry. Then, the core is taken from the trestles and parts which are lacking at the upper end and at the lower end (gunpowder chamber) are completed with clay. After drying, the core is baked. Biringuccio says that some masters additionally reinforce cores with iron wires. Others do not follow this idea, as it renders the extraction of the core from the mould difficult<sup>207</sup>.

A mould for the breech of the gun is made separately. The way it is made depends on whether the gun is to be round or fluted. In the first case, some masters made a wooden or clay pattern for the breech using a lathe. In the other case, flutes are made by hand in wood or clay. Clay or wooden cornices or other projections are placed on the model. Clay or wax can be used to make leafwork or other ornaments. Biringuccio also says that he himself always added full-relief figurines and other ornaments to the breech. These were made of wax or potter's clay. The pattern is then covered with clay, mixed with cloth clippings, and this way the mould proper is made. Then, the so-called male part of the joint connecting the breech mould and the main mould is constructed. In order to make sure that it will exactly fit into the main mould, it should be modelled with a small strickle or with compasses. The mould is reinforced with iron wire and a cage of iron rings and plates. Using fire or other means, one extracts the pattern from the mould. After drying, the mould is covered with ashes and baked<sup>208</sup>.

The next chapter discusses ways to make a disc or plate which will hold the core in the mould. One way is to make this disc as part of the core. If this was not done, a layer of clay is placed on a flat surface. The clay should be as thick and wide as the disc which was made at the feeding head of the mould for the main part of the barrel. After drying,

the clay is marked with compasses and cut to shape, so that it fits into the empty space at the feeding head. In the centre of the disc a hole is cut – its diameter should equal the thickness of the core. When the core is inserted through the hole, it must pass exactly through the centre of the mould and should fit into the afore-mentioned iron ring at the bottom of the mould. If it is decided that the disc will be part of the core (which Biringuccio finds to be a better solution), a notch is made at the top of the wooden board attached to the trestles and used to smoothen the core. When this notch is filled with clay, it makes an elevation which will fill the opening above the feeding head<sup>209</sup>.

Various ways to make the placing at the end of the gun which will hold the core in the centre of the mould are once again discussed in a separate chapter. Here, Biringuccio states a more precise position of the iron ring, saying that it should be put in the mould at the height of the last cornice, one *palmo* or half a *braccio* from the bottom of the mould. At the top of the main mould, instead of the afore-mentioned clay disc, it is also possible to use an iron collar. It is similar to that used at the foot of the mould. Biringuccio, however, says that he prefers to use the disc. When the core is put into the mould with the use of a pulley, the mould should rest in a pit in front of the furnace<sup>210</sup>.

Attention is also paid by Biringuccio to the problem of entrances and vents in moulds. Vents are necessary to allow the air to escape from the mould when the bronze enters the mould cavity. Generally, Biringuccio says that the more vents and the wider the entrances are, the better<sup>211</sup>. Then, issues of baking of moulds are discussed. Baking is necessary in order to get rid of moisture and moulds for guns can be baked in two or three ways. The main mould is baked from inside with dry wood. The mould may be laid on its side and heated until red. The final result is achieved after 3-4 hours. It is also possible to place the mould in an upright position over a little furnace. The process must proceed slowly and with no draft for flames. Large moulds may be baked in pits, while cores should be baked horizontally, being placed on pieces of bricks. A brick structure is then built around the core and it is filled with charcoal. After baking, the core is covered again with wash ashes and egg white. Breech moulds can be baked in a brick circle which is filled with charcoal. The mould is placed over it with the cavity downwards, but it must not touch the charcoal. Before casting, moulds must be cooled and any cracks should be plastered with egg white, crushed brick and quicklime. They must also be cleaned inside and

<sup>209</sup> Biringuccio, *The Pirotechnia*, Book VI, Chapter 8, p. 245-246.

<sup>210</sup> Biringuccio, *The Pirotechnia*, Book VI, Chapter 8, p. 246-248. According to the editors, there are two Chapters 8 in Biringuccio's work, *ibid.*, p. 246

<sup>211</sup> Biringuccio, *The Pirotechnia*, Book VI, Chapter 9, p. 248-249.

<sup>207</sup> Biringuccio, *The Pirotechnia*, Book VI, Chapter 6, p. 240-243.

<sup>208</sup> Biringuccio, *The Pirotechnia*, Book VI, Chapter 7, p. 243-245.

covered with a layer of ashes of a young ram's horn. After all the pieces of the mould are fitted together, a well-shaped pit is made in front of the melting furnace, as guns should be cast in an upright position. The pit's depth should somehow exceed the length of the mould, so that the bronze can easily run into it. After the core is inserted precisely in the middle of the mould, casting should start immediately, so that the mould does not absorb moisture from the soil<sup>212</sup>.

Chapter 11 offers a series of admonitions and additional pieces of advice. It is said that the furnace must be well heated and the metal must be properly charged into it. Bronze must be completely liquefied and to support this it is possible to add some tin. Eventually, it is necessary to have enough metal in the furnace to fill the mould to the point of overflowing<sup>213</sup>. It is interesting, however, that Biringuccio does not state a precise composition of bronze used for gun casting. In an earlier part of his book, he says that the usual composition of bronze is 8-12 pounds of tin per 100 pounds of copper (i.e., 7.41-10.71% Sn and 89.29-92.59% Cu). For bells, the recommended proportion is 23-26 pounds of tin (i.e., 18.70-20.63% Sn and 79.37-81.30% Cu). Biringuccio says that for "all other works" one uses the proportion of 12 pounds or more (i.e., from 10.71% upwards)<sup>214</sup>. With regard to casting, a very important issue is the melting loss of material during the process. Depending on the kind of material, the decrease can usually be c. 5-8 per 100, but to be on the safe side, masters usually assume the loss to be at the level of 10 per 100<sup>215</sup>. Then, Biringuccio says that while the gun mould is near the point of overflowing, it is advisable to add some tin into the furnace or the channels, in order to make sure that the feeding head is filled with alloy of proper unctuousness. Due to this, the gun mouth will be solid and without holes<sup>216</sup>.

After casting, the finishing process takes place. The gun is taken from the pit and freed of clay. The iron spindle in the middle of the core is removed first and then the feeding head is sawed off. Ornaments of the gun are uncovered and the surface of the barrel is gently hammered to make it smooth. A chisel-like tool with a steel point is used to remove the clay from the space for the projectile and gunpowder. Then, a small steel drill is used to make the touch hole. Biringuccio recommends to bore guns, both small and large, as it is done with arquebuses or iron muskets. For this purpose, a special device can be used. It can be powered either with a treadmill or by hand.

<sup>212</sup> Biringuccio, *The Pirotechnia*, Book VI, Chapter 10, p. 249-254.

<sup>213</sup> Biringuccio, *The Pirotechnia*, Book VI, Chapter 11, p. 255-260.

<sup>214</sup> Biringuccio, *The Pirotechnia*, Book V, Chapter 3, p. 210-211.

<sup>215</sup> Biringuccio, *The Pirotechnia*, Book VI, Chapter 12, p. 267.

<sup>216</sup> Biringuccio, *The Pirotechnia*, Book VII, Chapter 5, p. 267.

The working part of the device is a spindle with a square piece of steel with four sharp corners at its top. The gun is firmly secured on a wooden board resembling a small cart. Thanks to rollers and a windlass, the gun can move when pulled. The spindle is rotated and the gun is bored by means of being pulled forwards, so that the steel drill goes into the bore. The process is repeated two or three times and each time the cut of the steel drill is slightly increased to make the bore smooth. Finally, one tests the gun by firing it three times and the last shot is done with the quantity of gunpowder equal to the weight of the ball<sup>217</sup>.

Biringuccio also devotes a separate chapter to cast iron projectiles. He says that such projectiles have a very powerful effect and they were first used in Italy during the invasion of the Kingdom of Naples by King Charles (VIII) of France (which took place in 1494 – GŽ). Such balls are cast with the use of blast furnaces. Moulds for such projectiles are made from the same kind of iron. First, a wooden or clay ball is made, with dimensions corresponding to the ball one wants to cast. It is also possible to use iron or lead balls. Half of the ball is placed in a board or in clay, while the other half is greased with oil or lard. Over it, a half-pattern for the mould is made from plaster of Paris or clay. The other half is made analogously. After removing of the ball from the pattern, openings for gates and vents are made and holes to peg the parts together are prepared. The half-patterns are then covered with ashes or greased with oil, and each half is individually covered with moulding clay. After making and baking mould carriages, the moulds are filled with bronze or molten iron and thus a metal mould for casting balls is ready. For the casting process, a forge with bellows operated with a water wheel is necessary. In front of the bellows' tuyères there is a hearth made from non-melting stone. It should be round, 1.5 *braccio* high and 3/4 *braccio* wide, with a hole for melted metal in its bottom. Inside, the hearth is covered with plaster and ashes, and then it is baked. When ready, the hearth is filled with charcoal, fire is started and the blast is applied. When the fire burns well, pieces of iron are added and when they are liquefied, the moulds are filled until the iron overflows. Biringuccio also mentions a way to make iron bullets for muskets and arquebuses. A cube is formed from a rod by hammering. The cube is heated and it is placed on an anvil with a hollowed hemisphere. Using a similarly hollowed punch, one strikes the cube so that it becomes round. Such projectiles are said to be better than those cast in moulds, as they are made from good soft iron with no internal corruption<sup>218</sup>.

Some interesting remarks can be also found in the manual of J. Jakubowski. In the introduction to his work,

<sup>217</sup> Biringuccio, *The Pirotechnia*, Book VII, Chapter 8, p. 307-312.

<sup>218</sup> Biringuccio, *The Pirotechnia*, Book VII, Chapter 9, p. 319-321.

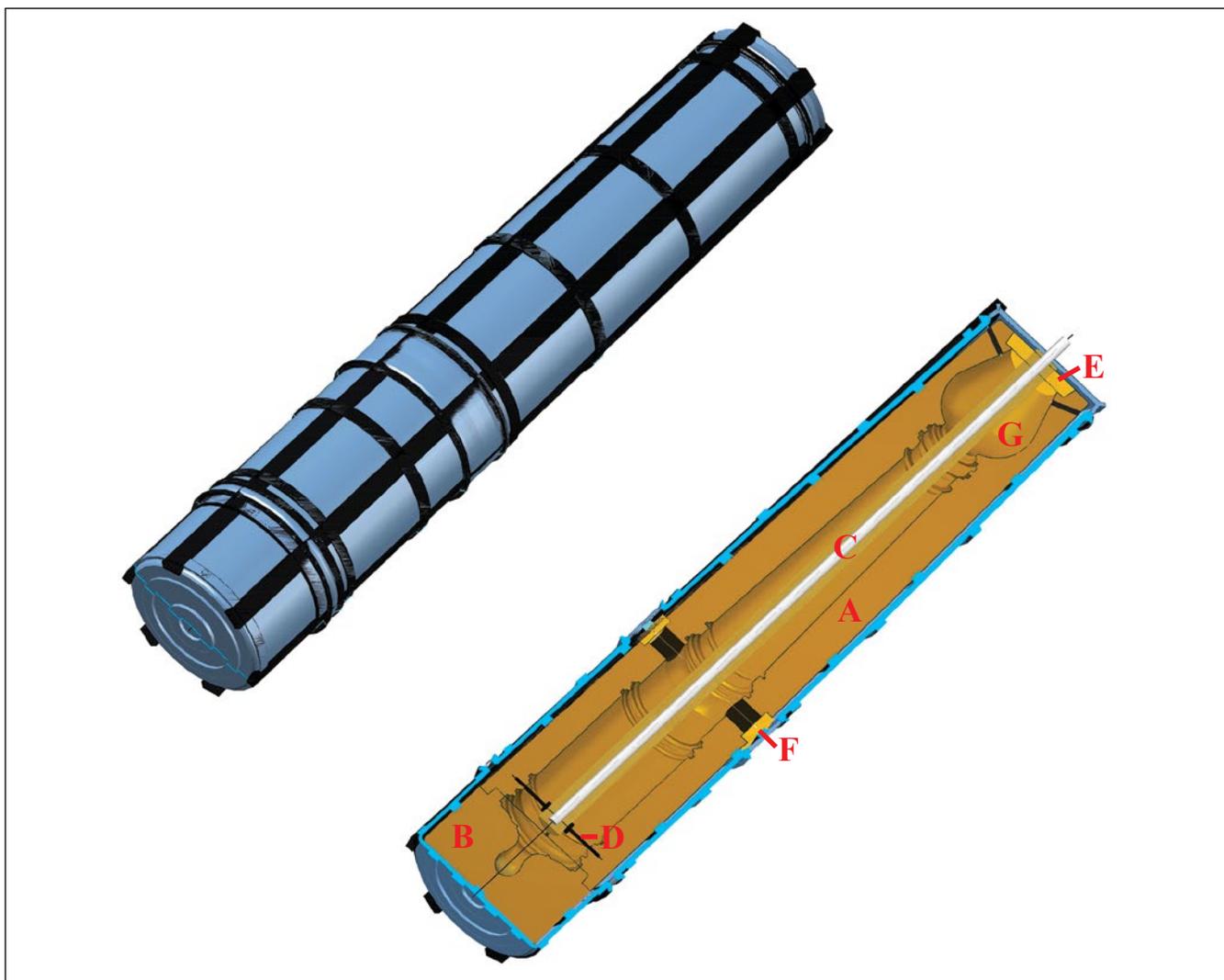


Fig. 1. A complete gun mould. After Biringuccio, *The Pirotechnia...*, Appendix A, p. 452, Fig. VI, adapted from Saint Remy, *Memoires d'artillerie*, 1697. Drawing G. Żabiński. A – main body mould; B – breech mould; C – core; D – iron chaplets holding the core; E – clay disc holding the core; F – bricks closing the trunnion cavities; G – feeding head.

he says that some early (i.e., Late Medieval) cannons were made from cast iron, but they proved to be too brittle. For this reason, another raw material, being a mixture of copper, brass and tin started to be used<sup>219</sup>. Jakubowski also expressed a rather negative opinion on the quality of forged iron cannons. For non-ferrous metals, he says that copper alone could be used, but it becomes too porous during the casting process. This problem can be solved by adding tin and brass. There are various formulae for a good alloy, such as: 100 pounds of copper, 9 pounds of tin and 6 pounds of brass; 100 pounds of copper, 10-20 pounds of tin, 10 pounds of brass; 100 pounds of copper, 11 1/8-12 pounds of tin and no brass<sup>220</sup>.

The description of cannon barrel casting by Jakubowski was thoroughly discussed by M. Dąbrowska. This author says after J. Piaskowski that the first layer of clay was mixed with 1/3 of horse dung, while the second one contained

2/3 of sand and 1/16 of cow fur. The last layer (the external surface of the false model) was composed analogously, but the clay had to be of finest quality. With regard to the mould as such, its first layer was sometimes composed of fine clay mixed with brick powder with an addition of 1/16 of cow fur. The proportion between the clay and the brick powder was 1:1. The second layer was of the same composition, while the third one contained clay mixed with 1/3 of horse dung and 1/3 of cow fur<sup>221</sup>.

The process of making the cannon mould is basically similar to the description offered by Biringuccio. One difference is that Jakubowski explicitly mentioned the use of wax models of holders, which are fixed on the pattern of the cannon. When the mould is fired, the wax melts and leaves cavities for the metal. Another, more significant difference is that Jakubowski recommends to cast barrels solid and then drill the entire bore, without the core in the mould, although

<sup>219</sup> *Nauka Artyleryi*, Introduction, p. 5-6.

<sup>220</sup> *Nauka Artyleryi*, Part II, Chapter I, p. 177-183.

<sup>221</sup> Dąbrowska 2009, 28-32.

he also says how to prepare and use such cores. The presence of the core diminished the amount of metal poured into the mould, preventing it from becoming dense enough. Furthermore, the core can move to the side and thus the bore will not be exactly on the axis of the barrel<sup>222</sup>. It is known that due to difficulties in casting of guns with the use of cores in moulds, one started to cast solid barrels and then bore them. A date of 1713 is suggested for the first application of this process in France. It has also been said that guns cast in moulds with cores were banned in 1747 in France, in 1756 in Sweden and in 1775 in England<sup>223</sup>.

### Technology of gun barrel manufacture in the Teutonic Order's state

Having done this brief overview, it is possible to examine what steps of technological processes of gun barrel manufacture can be seen in written sources and in the archaeological record. Furthermore, the problem of the chemical composition of copper alloy guns will be discussed, against the background of comparative data.

Only a few pieces of information concerning technological processes can be found in inventories, while data from account books is more abundant. There are also some mentions in narrative sources:

- 4 unusable lead bullet guns which were iron-forged (*loethbochszen dy togen nicht und seynt gesmytd von eysser*) were recorded in Gerdaun (Żeleznodorożny), the Procurator's Office in the Commandery of Königsberg (Kaliningrad) in 1420<sup>224</sup>
- 4 barrels of osmund iron (*vas osemundes*) were mentioned among gun resources in the Commandery of Christburg (Dzierzgoń) in 1434<sup>225</sup>. The use of such material for gun manufacture is testified to by a mention from 1411 concerning the castle of Marienburg (Malbork). It says that 3 barrels of osmund (*vas osemund*) were bought in Elbing (Elbląg) upon the request of the Grand Master. A certain master Johan was supposed to forge guns using this iron (*do von meyster Johan bochszen smeden sal*)<sup>226</sup>
- data on purchases of charcoal (*kolen*) for gun casting at the Order's capital castle is known from 1409, 1411, 1412, 1413, 1415<sup>227</sup>. Analogous expenses were recorded in the Old Town of Elbing (Elbląg) in 1410<sup>228</sup>

- purifying of copper (*coppers zu lutern*) with regard to gun casting was recorded at the castle of Marienburg (Malbork) in 1403<sup>229</sup>
- expenses on servants helping a gun-founder melt copper (*mitteknechten di haben dem buchsengisser geholfen kopper bornen*) and especially on those operating bellows (*knechten di haben geblose czum copperbornen und dem buchsengisser*) were recorded at the Order's capital castle in 1419<sup>230</sup>. There was also a series of such expenses in 1420. An especially intriguing mention concerns casting of a band for guns (*band czu buchszen czu gissen*)<sup>231</sup>. It may have been some sort of non-ferrous metal reinforcement for gun barrels
- purchase of 1 stone of wax (*wachs*) was mentioned at the castle of Marienburg (Malbork) in 1408, with regard to the casting of the *Grosse Bochse*<sup>232</sup>. In the same year, another 0.5 stone was bought, due to a need to cast the breech part again<sup>233</sup>. Yet another 0.5 stone was purchased in early September 1408<sup>234</sup>. In 1409, a purchase of 10 pounds of wax for the gun mould for holders (*wachs zur bochszenforme zu rinkoren*) was mentioned, concerning the casting of the *Bochse nehest der grosen*<sup>235</sup>. Furthermore, 3 pounds of wax (*wachs*) were bought with regard to gun casting in that year, probably for 2 medium-sized cannons<sup>236</sup>. Another 18 pounds for a gun mould (*bochszenforme*) were also bought<sup>237</sup>
- making of moulds (*formen*) and gun casting (*bochsengissen*) was recorded at the castle of Marienburg (Malbork) in 1401, 1402, 1403, 1408, 1409, 1411, 1412, 1413, 1414, 1415, 1417, 1418, and 1420<sup>238</sup>. Gun casting was also recorded in the Old Town of Elbing (Elbląg) in 1410, 1411, 1414, and 1417<sup>239</sup>, in Gdańsk (Danzig) in 1409<sup>240</sup> and in 1414<sup>241</sup>, and in Toruń (Thorn) in 1460<sup>242</sup>. Manufacture of guns was also mentioned in Kwidzyn (Marienwerder)

<sup>229</sup> MTB, p. 217; Rathgen 1922, 24; Rathgen 1928, 404.

<sup>230</sup> ABMH, p. 334; Żabiński 2014, 131.

<sup>231</sup> ABMH, p. 361.

<sup>232</sup> MTB, p. 483; Engel 1897-1899, 230; Rathgen 1922, 26; Żabiński 2012, 31; Strzyż 2014, 217.

<sup>233</sup> MTB, p. 496; Engel 1897-1899, 230; Rathgen 1922, 26; Żabiński 2012, 32; Strzyż 2014, 217.

<sup>234</sup> MTB, p. 502; Rathgen 1922, 27; Żabiński 2012, 34; Strzyż 2014, 217.

<sup>235</sup> MTB, p. 558; Engel 1897-1899, 231; Rathgen 1922, 29; Rathgen 1928, 406; Strzyż 2014, 217.

<sup>236</sup> MTB, p. 545; Engel 1897-1899, 231; Rathgen 1922, 28; Rathgen 1928, 405; Strzyż 2014, 217.

<sup>237</sup> MTB, p. 547; Engel 1897-1899, 231; Rathgen 1922, 28; Rathgen 1928, 405.

<sup>238</sup> MTB, p. 119-120, 140, 201, 217, 479-480, 483, 496, 500-502, 506, 511, 544-545, 547, 557-559, 571, 590-591; ABMH p. 25, 27-28, 46, 61-62, 104-105, 126, 176, 252, 311, 354, 357, 359, 361.

<sup>239</sup> NKRSME 1, p. 229; NKRSME 2, p. 10, 31, 77; EK, p. 242, 255.

<sup>240</sup> MTB, p. 554, 559.

<sup>241</sup> NKRSME 2, p. 78.

<sup>242</sup> KKMT, No. 33.

<sup>222</sup> *Nauka Artyleryi*, Part II, Chapter I, p. 184-192.

<sup>223</sup> Biringuccio, *The Pirotechnia*..., p. 223, editors' note; Buchwald 2008, 325-328; Rathgen 1928, 356; M. Dąbrowska erroneously assumes that solid gun barrels may have been cast at the Order's capital, Dąbrowska 2009, 32; a similar mistake was made by J. Szymczak, see Szymczak 2004, 90-92.

<sup>224</sup> GÄDO, p. 6; Rathgen 1922, 12, 81; Rathgen 1928, 397.

<sup>225</sup> GÄDO, p. 141.

<sup>226</sup> MKB, p. 252; Klimek et al. 2013, 93.

<sup>227</sup> MTB, p. 558; ABMH, p. 25, 46, 91, 176, 188-192; Żabiński 2014, 129.

<sup>228</sup> NKRSME 1, p. 229.

- in an establishment called *eyser mole* (“iron mill”) as part of war preparations of Grand Master Albrecht von Hohenzollern in 1517-1519<sup>243</sup>. During the war, casting of guns upon the order of the Grand Master with the use of bells from destroyed churches was recorded for 1520<sup>244</sup>. Casting of a huge cannon (*grosze buxe*) in Gdańsk (Danzig) with the use of 145 Zentners of copper was mentioned for Spring 1523<sup>245</sup>
- expenses on clipped animal fur and ashes for smoothing of the gun mould (*vor schorhor und vor asche zur forme zu schlichten*) were recorded in 1409 at the Order’s capital castle, with regard to the *Bochse nehest der grosen*<sup>246</sup>. In the same year, 1 stone of hemp was bought for making moulds for 2 medium-sized cannons (*steyn hanf zu den formen zu machen zu den 2 mittelbochsen*)<sup>247</sup>. In 1414, 24 stones of beaten tow (*geslagen tou*) 58 pounds of best yarn (*pest garnes*) were bought by the authorities of the Old Town of Elbing (Elbląg). It was explicitly stated that the tow was intended for guns (*wart geslagen czu den buchsen*)<sup>248</sup>. It can be naturally supposed that both tow and yarn were meant to be used for gun moulds
  - expenses on 2 pounds of cord or wire (*droth*) and a sack of combed wool (*schorwolle*) for a master gunner (*bochsenschotcz*) Conrad were recorded at the castle of Marienburg (Malbork) in 1415. It could be suggested that these materials may have been used for making of gun moulds. This is supported by another mention from that year, stating expenses on digging clay for guns (*leym ... czu bochsen*) and on making gun moulds (*bochsen formen*)<sup>249</sup>. Clay was also mentioned among the expenses of the Old Town of Elbing (Elbląg) on gun-casting in 1410<sup>250</sup>
  - from 1412 there comes a mention of polishing of guns (*buchssen ... slefen*) at the castle of Marienburg (Malbork)<sup>251</sup>, which obviously implies some sort of finishing works. The same can be said about a mention cleaning of newly cast guns (*dy buchsen reyn czu machen*) in 1413<sup>252</sup>
  - there are mentions of testing new guns in 1413 (a payment for *knechten dy dem buchsenschutczen dy buchsen holfen legen do man sy beschos*)<sup>253</sup>

- 13 large drills for boring pipes (*grosse nefeger, dy roren domete czu boren*) were recorded in the inventory of the Old Town of Elbing (Elbląg) in 1413<sup>254</sup>. It could be supposed that they may have been used for boring of cannon barrels
- 3 large drills (*grose nebiger*) were mentioned among the resources of firearms and ammunition of the Commandery of Nowa Nieszawa (Nessau) in 1432<sup>255</sup>
- 1 iron gun drill (*eisern buchsennebiger*) was recorded in the Procurator’s Office of Preussisch Mark (Przezmark) in 1507<sup>256</sup>
- the anonymous author of the Teutonic Order’s firearms inventory, dated to about 1523, reported to the Grand Master that he had ordered to bore and make ready a number of guns in Königsberg (Kaliningrad), so that they were ready to be used in the field (*von neunhen lassen boren und fertig machen mit aller notthurfft, da man es wol ins feldt gebrawchen mag*). These guns included: 3 “red-backed shrikes” (*dorndreher*, some sort of light guns<sup>257</sup>), 2 stone cannonball guns (*steynbuchsen*), 2 new serpentes (*neuhe schlange*), 8 organ guns (*orgelpfeyffen*), 2 small falconets (*falkcennethlen*) and 2 guns on trestles (*bockpuchsel*). Furthermore, he also ordered to cast anew (*von neuhes lassen gyessen*) other guns: 4 quarter-serpentes (*quartirschlangen*) weighing 4 Zentners each, and 1 small falconet (*falckenmethlen*), weighing 5 Zentners<sup>258</sup>

As it can be seen, the sources inform about numerous stages of gun barrel manufacture: purification of metal, making and smoothing of moulds with the use of clay, wax, hemp, yarn, wool, fur and ashes, the casting process itself, polishing and cleaning of barrels, and eventually firing trials. Attention is drawn to rather small amounts of wax, which seems to confirm that it was used to make patterns of holders and decorative elements. On the other hand, it cannot be excluded that in the case of smaller guns the entire model may have been made of wax, using the *cire-perdue* technology<sup>259</sup>. There is no mention of boring of gun barrels in the Order’s account books. This can be to some degree explained by the very nature of such sources, which were meant to record expenses and not individual stages of manufacturing processes. On the other hand, the presence of gun drills in the inventories seems to confirm the application of this technology<sup>260</sup>. A further support is given

<sup>243</sup> *Die Danziger Chronik...*, p. 446; Żabiński 2014, 125.

<sup>244</sup> *Preussische Chronik 2*, p. 547; Regesta, No. 24146, p. 270, No. 27798, p. 478.

<sup>245</sup> *Ferber-Chronik*, p. 534; Żabiński 2014, 126.

<sup>246</sup> MTB, p. 559; Engel 1897-1899, 231; Rathgen 1922, 29; Rathgen 1928, 406.

<sup>247</sup> MTB, p. 544; Engel 1897-1899, 231; Rathgen 1922, 28; Rathgen 1928, 405.

<sup>248</sup> NKRSME 2, p. 79-80; Rathgen 1922, 71; Rathgen 1928, 429.

<sup>249</sup> ABMH, p. 176; Rathgen 1922, 57-59; Rathgen 1928, 422; Świątosławski 1993, 24; Żabiński 2014, 129-130.

<sup>250</sup> NKRSME 1, p. 229.

<sup>251</sup> ABMH, p. 68.

<sup>252</sup> ABMH, p. 105.

<sup>253</sup> ABMH, p. 109.

<sup>254</sup> EK, p. 254; Rathgen 1922, 72; Rathgen 1928, 430; Chodyński 1996a, 20, 22; Chodyński 1997, 77-78; Szymczak 2004, 90; Strzyż 2014, 222.

<sup>255</sup> GÄDO, p. 484-485; Strzyż 2014, 222.

<sup>256</sup> GÄDO, p. 147; Żabiński 2014, 125.

<sup>257</sup> Boenheim 1897-1899, 58; Goetz 1985, 33-34; Chodyński 1996b, 54; Szymczak 2004, 66, 339, Tab. 20.

<sup>258</sup> Biskup 1984, 100-101; Żabiński 2014, 125.

<sup>259</sup> Schmidtchen 1977a, 52-53; Dąbrowska 2009, 33; Stępiński et al. 2013, 156, 186.

<sup>260</sup> Dąbrowska 2009, 40; Żabiński 2012, 34.

by the direct mention of barrel boring in the anonymous inventory from about 1523.

Interesting data on gun casting at the Order's capital castle was yielded by archaeological research. Excavations carried out in the central part of the Fore-Castle, in the area of the Teutonic foundry yielded architectural remains of part of this building. Foundations in its individual parts were constructed in a different manner, which was interpreted as traces of internal partitions corresponding to various stages of manufacturing processes. Other finds included fragments of moulds, burnt wire and hearth bricks. There were over 300 fragments of cylindrical clay ones, with numerous metallic dripstones. Other finds were identified as fragments of metal-clay moulds. There were also numerous pieces of rubble with a remarkable greenish tone, testifying to a high content of copper compounds. A few clay forms were restored and based on them it was possible to identify internal diameters of cast artefacts. These were between 33 and 43 cm, so it is possible that larger cannons were cast in them. The thickness of these fragments is between 3 and 5.5 cm and they have a multi-layered structure. Walls of other mould fragments were profiled, so it was assumed that these forms were used for casting cannon breeches or parts of small bells. The fact that bronze artefacts were cast in them is evidenced by their internal surfaces, covered with pieces and dripstones of metal of greenish tone. In few fragments there are hollowings, which may have formed small rims on cast artefacts. In sections of moulds one can clearly see traces of forming of subsequent layers of clay which were applied as the mould was made. Furthermore, impressions of grass were identified. The first internal layers (1-1.5 cm thick) of other fragments of moulds are made of metal. The analysis of their chemical composition demonstrated that it was an alloy with the content of 49.64-68.78% of CuO. Furthermore, a considerable share of silica and SnO was found. Grey fired clay on external surfaces of moulds demonstrates that the external coating was made from clay. In one case it was possible to identify the diameter of a ready artefact – it was about 35 cm. It was tentatively assumed that these fragments were parts of casting moulds of previously unknown structure and that such moulds could be used repeatedly. For this purpose, they should be composed of at least two parts (analogously to stone moulds), which could be opened after the completion of the manufacturing process, so that a ready artefact could be taken out. On the other hand, these may have also been ceramic forms, which were reinforced with a metallic layer inside. Forms of repeated use could no question speed up manufacturing processes and they could guarantee that calibres of cannon barrels would be standardised. On the other hand, it is believed that casting forms made from metal were used sporadically only. Clay moulds from Marienburg (Malbork) were made from subsequent layers of clay with a leaning admixture of sand. For the sake of reinforcing (and perhaps also to make the

mould porous enough in order to provide escape for gases), the second (?) layer was wrapped with grass and sedge. Regrettably, fragments of moulds of complete thickness (from 10 to over 12 cm) did not survive and all that was found were internal parts of mould walls. Concerning metal-clay moulds, the first internal layer (which was in a direct contact with the cast metal) was made from bronze with an addition of silica. Subsequent layers were made from moulding mass whose chief component was clay. However, as no evidence of using such forms has been discovered so far, M. Dąbrowska says that analyses of larger series of samples from other foundries would be necessary<sup>261</sup>.

The next issue is the chemical composition of copper alloy guns manufactured in the Order's state. Data concerning cases where such an estimation is possible is gathered in the table below. Of course, results must be treated with care, as it is hardly possible to calculate the loss of individual elements in the process of casting. Furthermore, it would be even more difficult to calculate the loss of material if a repeated casting (as in the case of the Order's *Grose Bochse*) was necessary<sup>262</sup>. What is more, in case several guns were cast at one time from a given amount of raw material, it is not always clear whether they were of equal weight and with equal proportions of individual elements. Thus, the calculations below were done using "raw data" from the sources (Tab. 3).

It seems that several interesting observations can be made<sup>263</sup>. Both 6 small *steynbochsen* and 2 *steynbochsen* cast at Marienburg (Malbork) in 1401 were cast from almost pure copper (c. 97-97.5% Cu and c. 2.5-3% Sn). As these were all rather small cannons (perhaps c. 120 kg each, assuming that they were of equal weight), it was perhaps believed that such a chemical composition would be enough to provide them with enough toughness. On the other hand, the share of tin is much greater in the case of 2 *veuglaires* with 3 powder chambers for each, cast at Marienburg (Malbork) in 1403. Assuming their equal size, the weight of one gun (the case and 3 powder chambers) would be slightly more than 100 kg. As the weight of the powder chamber may have been about 1/3-1/4 of the weight of the barrel, one receives c. 53-57 kg for the chase and c. 17-19 kg for 1 chamber, i.e., c. 70-76 kg for the entire set. This means that these *veuglaires* were significantly smaller than the afore-mentioned *steynbochsen*. On the other hand, it was perhaps believed that *veuglaires* should be made from tougher metal, due to their higher rate of fire. Furthermore, in the case of these guns it is possible to estimate the loss of

<sup>261</sup> Dąbrowska 2007, 307-311; Figs. 5-8; Dąbrowska 2009, 22-29, Figs. 2-6, 32, Fig. 11, 36; see also Józwiak and Trupinda 2007, 412-413; Stępiński et al. 2013, 182-183; Strzyż 2011, 36-37, Tab. XVIII; Strzyż 2014, 222-223, Fig. CXVIII.2-3,6.

<sup>262</sup> Żabiński 2012, 32.

<sup>263</sup> For a discussion on this data see also Rathgen 1922, 35-36; Rathgen 1928, 409-410.

<b>6 small guns (cleyne bochsen, in all probability steynbuchsen) Marienburg (Malbork), Teutonic Order, 1401</b>								
Raw material	Schiffs-pfund	Zentener	Stein	Lisp-fund	(Mark) Pfund	Krompfund	Total kg (%)	Source
Copper		14.5					704.7 (96.99%)	MTB, p. 99, 119-120
Tin			1.5		3		21.87 (3.01%)	MTB, p. 119
Total weight* <b>726.57 kg (100%)</b>								
* The source says that the total weight of these guns was 15 Zentners (729 kg) (MTB, p. 120)								
<b>2 guns (buchsen, in all probability steynbuchsen) Marienburg (Malbork), Teutonic Order, 1401</b>								
Raw material	Schiffs-pfund	Zentener	Stein	Lisp-fund	(Mark) Pfund	Krompfund	Total kg (%)	Source
Copper		5					243 (97.56%)	MTB, p. 140
Tin					15		6.075 (2.44%)	MTB, p. 140
Total weight <b>249.075 kg (100%)</b>								
<b>2 guns (buchsen, veuglares with 3 chambers each, in all probability steynbuchsen) Marienburg (Malbork), Teutonic Order, 1403*</b>								
Raw material	Schiffs-pfund	Zentener	Stein	Lisp-fund	(Mark) Pfund	Krompfund	Total kg (%)	Source
Copper		4	0.5				201.285 (89.08%)	MTB, p. 217
Tin		0.5				1	24.665 (10.92%)	MTB, p. 217
Total weight ** <b>225.95kg (100%)</b>								
* Raw material was bought in Toruń (Thorn), so it is uncertain what stone was used in the account book								
** The source says that the total weight of these guns was 4 Zentners and 20 pounds (202.5 kg) (MTB, p. 217). The loss of material can be estimated at c. 23.45 kg (10.38%)								
<b>Grose Bochse, Marienburg (Malbork), Teutonic Order, 1408<sup>264</sup></b>								
Raw material	Schiffs-pfund	Zentener	Stein	Lisp-fund	(Mark) Pfund	Krompfund	Total kg (%)	Source
Copper		243		4	47		11857.995 (86.17%)	MTB, p. 480, 501, 506
Tin	8.5	8.5		17.5	12	2	1785.565 (12.98%)	MTB, p. 480, 501, 511
Lead		2			48		116.64 (0.85%)	MTB, p. 506
Wax			2				27.54	MTB, p. 483, 496, 502
Total weight* (excluding wax) <b>13760.2 kg (100%)</b>								
* It is difficult to say to what extent this calculation reflects the reality, as the source mentions repeated castings of both the chase and the breech (MTB, p. 506, 496)								
<b>(Cleyne) Lange Bochse, veuglaire with 3 chambers, Gdańsk (Danzig), Teutonic Order, 1409</b>								
Raw material	Schiffs-pfund	Zentener	Stein	Lisp-fund	(Mark) Pfund	Krompfund	Total kg (%)	Source
Copper							?	MTB, p. 559
Tin							?	MTB, p. 559
Lead							?	MTB, p. 559
Total weight* <b>11.5 Zentners or 558.9 kg</b>								
* The source states the total sum spent on raw materials (41 Marks 10 Scots 18 Denars for copper, tin and lead), without specifying the weight of each component. Then, the total weight of the gun is given.								
<b>Bochse nest der grosen, Marienburg (Malbork), Teutonic Order, 1409</b>								
Raw material	Schiffs-pfund	Zentener	Stein	Lisp-fund	(Mark) Pfund	Krompfund	Total kg (%)	Source
Copper		79.5			50		3883.95 (82.57%)	MTB, p. 557
Tin	3		25.5	4		6	819.885 (17.43%)	MTB, p. 557-558
Wax					10		4.05	MTB, p. 558
Char-coal	234						34117.2	MTB, p. 558
Total weight (excluding wax and charcoal) <b>4703.835 kg (100%)</b>								
<b>Lange Bochse cast by Steynkeller, Marienburg (Malbork), Teutonic Order, 1409</b>								
Raw material	Schiffs-pfund	Zentener	Stein	Lisp-fund	(Mark) Pfund	Krompfund	Total kg (%)	Source
Copper		33			36		1618.38 (94.33%)	MTB, p. 590
Tin		2					97.2 (5.67%)	MTB, p. 591
Total weight (excluding wax and charcoal) <b>1715.58 kg (100%)</b>								

Tab. 3. Estimation of the chemical composition of copper alloy guns cast in the Teutonic Order's state in Prussia in the early 15<sup>th</sup> c.  
Author: G. Żabiński.

raw material during the casting process. It was about 10%, which is in line with the afore-mentioned data given by Biringuccio.

For the largest cannons (the *Grose Bochse*, the *Bochse nest der grosen* and the *Lange Bochse* cast by Steynkeller), the share of tin is also high. In the case of the *Grose Bochse*, it is almost 13%. This may imply that for such a large cannon extra toughness was needed<sup>265</sup>. Attention is also drawn to the presence of lead (less than 1%). According to the source, lead was used during the repeated casting of the chase (*als man das vorder ende anderweyt gos*) only<sup>266</sup>. Such a quantity of lead could improve the metal's castability. It cannot be excluded that the addition of lead was also meant to provide the metal with greater elasticity (and perhaps also toughness), but the effect may have been adverse<sup>267</sup>. Perhaps for the same reason lead (in an unknown proportion) was used for the *Cleyne Lange Bochse*, too. A strikingly high proportion of tin (almost 17.5%) was used for the *Bochse nest der grosen*. Such a high proportion of tin could still increase the toughness, at the cost of much less plasticity. Interestingly, the proportion of tin in the *Lange Bochse* cast by Steynkeller seems to be closer to that in smaller cannons than in the largest guns.

These figures may be compared with data offered by Jakubowski. Proportions of elements (copper, tin and brass, the latter being an alloy of Cu and Zn in different proportions, but usually with c. 65-70% Cu) which were stated by him can be re-calculated in the following manner:

- a. Cu 86.95%, Sn 7.83%, Cu, Zn 5.22%
- b. Cu 83.33%, Sn 8.33%, Cu, Zn 8.33% or Cu 76.92%, Sn 15.38%, Cu, Zn 7.69%
- c. Cu 89.29%, Sn 10.71%

As it can be seen, both the *Grose Bochse* and the *Bochse nest der grosen* with their high contents of Sn (almost 13% and almost 17.5% respectively) could somehow fit within these proportions, bearing in mind that the influence of tin and zinc on properties of the alloy would be similar. A proportion of less than 10-11% or 6-12% Sn is also stated by numerous authors<sup>268</sup>. Results of analyses of 18 bronze guns which were manufactured in the 16<sup>th</sup> c. in Vienna, Graz,

Innsbruck and Ragusa demonstrated that the content of Sn was between 3.4% and 10.5%, or 7.3% on average<sup>269</sup> (Tab. 4).

Much less can be said about the manufacture of iron guns. It seems that (at least until the late 15<sup>th</sup>-early 16<sup>th</sup> c.) no cast iron guns were made in the Order's state (cf. the afore-mentioned record from Königsberg (Kaliningrad) from 1415, making a distinction between iron guns and cast guns, *ysern und gegossen*<sup>270</sup>). There are also hardly any detailed mentions concerning the technology of assembling of iron guns from bars and rims. With regard to forging of guns, the afore-mentioned record from 1411 is of interest, as it evidences the use of osmund iron for this purpose<sup>271</sup>. Osmund was a Swedish term for iron received since the late 12<sup>th</sup> c. in early blast furnace processes (i.e., it passed through the liquid phase). Such iron was then refined in order to remove the excess of carbon and make it malleable. It physically appeared as small lumps or bars weighing c. 280 g. The content of carbon could vary from almost pure iron with c. 0.1% C to hypereutectoid steel with more than 1% C<sup>272</sup>. Regrettably, it is impossible to say now what kind of osmund was to be used for forging of guns in 1411, but it seems obvious that soft (less carburised) iron would be much better for this purpose.

#### Technology of metal gun projectiles manufacture in the Order's state

Data concerning technologies of manufacture of metal projectiles for firearms is less informative. Apart from the afore-mentioned records of raw materials, sources sometimes record tools used to make ammunition or mention some details of technological processes:

- 4 Marks were paid by the authorities of the Old Town of Elbing (Elbląg) in 1410 for a pan for a bullet-founder (*ene panne, de kofft de lotgeter*)<sup>273</sup>
- 2 skipponds of iron (*ysens*) were bought in 1412 for the smithing master (*smedemeyster*) at the castle of Marienburg (Malbork) for casting large projectiles for terrace guns (*in dy grosen gelote czu gissen czu den tarrasbochsen*)<sup>274</sup>
- a casting cauldron (*giskessel*) was mentioned among the resources of guns and gunpowder in the Commandery of Brandenburg (Ušakovo) in 1452<sup>275</sup>

<sup>264</sup> See also Posilge, *Chronik*, p. 292; Żabiński 2012, passim, with further scholarship (and with a slightly erroneous calculation concerning tin...).

<sup>265</sup> See also Rathgen 1922, 35-36; Rathgen 1928, 410.

<sup>266</sup> MTB, p. 506; Rathgen 1922, 22; Rathgen 1928, 405.

<sup>267</sup> Schmidtchen 1977a, 59; Rathgen 1928, 64, 207, 286; Żabiński 2012, 33; Strzyż 2014, 228-229.

<sup>268</sup> Buchwald 2005, 61; Buchwald 2008, 329; Dąbrowska 2009, 36 – c. 90% Cu and c. 10% Sn; Strzyż 2014, 224-225 – 87-93% Cu and 3-12% Sn, usually c. 90% Cu and c. 10% Sn; Rathgen 1928, 33, 64, 159; Fino 1974, 18 – 88-92% Cu and 8-12% Sn; Szymczak 2004, 92 – 6.7-11.5% Sn (most often 8-9%) or c. 8% Sn and 1.2-3.8% Zn).

<sup>269</sup> Williams and Paterson 1986, 190.

<sup>270</sup> GÄDO, p. 16.

<sup>271</sup> MKB, p. 252.

<sup>272</sup> Buchwald 2005, 337-340; Buchwald 2008, 230, 240-263, Tables 7.5, 7.9, with a discussion of osmunds from a c. 1450-1500 shipwreck found near Gdańsk (Danzig) in 1969; on the import of Swedish osmund see also Bogucka 1962, 103 ff., 193.

<sup>273</sup> NKRSME 1, p. 229; Rathgen 1922, 68; Rathgen 1928, 427.

<sup>274</sup> MKB, p. 282; Rathgen 1922, 79-80; Rathgen 1928, 433; Klimek et al. 2013, 93.

<sup>275</sup> GÄDO, p. 244; Stępiński et al. 2013, 180; Żabiński 2014, 127.

Cannon Name / Type, Weight, Remarks	Date	Provenance	Cu (%)	Sn (%)	Pb (%)	Zn (%)	Other (%)	Source
Bolt gun	14 <sup>th</sup> c.	Loshut, Sweden	92.3	3	3			Strzyż 2014, 231.
Hackbut	Late 14 <sup>th</sup> c.	Otepää, Livonia	94	4.5	1.6			Strzyż 2014, 231.
Hand-held gun	c. 1380	Kalisz, Poland	82.58	6	8.58	0.22		Strzyż 2014, 32-33, 227, Tab. 17, cat. No. 94.
Hand-held gun	Late 14 <sup>th</sup> c.-bef. 1450	Rakov, Bohemia	88.2	4.7	0.3	0.75	Sb 2.4	Strzyż 2014, 230, Tab. 19, cat. No. 84.
Hand-held gun	Late 14 <sup>th</sup> c.-bef. 1450	Rokštejn, Moravia	83.31	9.66	0.6		Sb 3.21	Strzyż 2014, 230-231, Tab. 19, cat. No. 85.
Große Frankfurter Büchse, 3500 kg	1394	Frankfurt am Main, Empire	87.4	12.6				Rathgen 1928, 33; Strzyż 2014, 224-225.
Cannon, c. 9100 kg	1409	Basel, Switzerland	95.37	4.63				Rathgen 1928, 477-478.
Faule Mette 8228 or 8730 kg	1411	Braunschweig, Empire	90	10				Rathgen 1928, 272-278.
Cannon	1421	Hildesheim, Empire		8				Strzyż 2014, 225.
Hand-held gun	1435-1475	Wenecja, Poland						Strzyż 2014, 10, 229, Tab. 17, cat. No. 119.
Hand-held gun	c. 1439?	Valečov, Bohemia	93.03	1.04	4.32		Sb 0.58	Strzyż 2014, 230, Tab. 19, cat. No. 90.
Cannon	1441	Metz, Empire		6.7				Strzyż 2014, 225.
Hand-held gun	Before 1444	Karpenstein (Karpien), Silesia	82.72	1.6	10.64		Ni 1.83	Strzyż 2014, 10 228-229, Tab. 17, cat. No. 112.
Hackbut	Before 1450	Smederovo, Serbia	90-93	4-6	1.3.5			Strzyż 2014, 231.
Cannon, the so-called Bombard of Muhammad, 17500 kg (average of 10 analyses)	1464	Turkey		11				Williams and Paterson 1986, 190, 193-194.
Hand-held gun	Before 1468	Mstěnice, Moravia	94.44	2.8	1.57			Strzyż 2014, 230-231, Tab. 19, cat. No. 81.
Hand-held gun	Before 1468	Mstěnice, Moravia	94	1.7	1		As 1.7	Strzyż 2014, 230-231, Tab. 19, cat. No. 82.
Bronze 12-pounder, 1475 kg (average of 3 analyses)	1650	Cast by Franz Roen, Glückstadt, Denmark		5-8	2-4	0.1-0.4		Buchwald 2005, 61, No. 38.

Tab. 4. Chemical composition of some copper alloy firearms, 15<sup>th</sup>-17<sup>th</sup> c. (only the most significant elements are listed, so they do not always sum up to 100%). Author: G. Żabiński.

- a copper mould for bullets (*coppenn forme zu geloten*), a stone mould (*gisssteyn*) and a casting ladle (*gisskelle*) were mentioned among resources of weaponry taken from Toruń (Thorn) to support the troops of the Prussian Confederacy besieging Świecie (Schwetz) in 1461<sup>276</sup>

Among this data, the mention of casting of iron projectiles for terrace guns is of most interest. As said above, Biringuccio referred to cast iron balls as a new and horrible invention, which was first seen in Italy in the late 15<sup>th</sup> c.<sup>277</sup>. Casting of iron cannonballs is testified to, e.g., in Freiburg im Breisgau in 1416, in the Austrian Alps since 1469, and

in Jernhytten in Scania in the early 16<sup>th</sup> c. (part of Denmark at that time)<sup>278</sup>. B. Rathgen also mentions an early example from 1373 concerning Trier<sup>279</sup>, from 1413 in Strassburg<sup>280</sup>, or from 1449 in Naumburg an der Saale<sup>281</sup>. Anyway, it seems that the data concerning cast iron cannonballs is among the first mentions of this process in Europe. Nothing closer is said by the source about the iron that was to be used for casting of projectiles in 1412. In this case, however, a possibly high content of carbon would be recommended, as it would decrease the temperature of melting of metal (which is about 1538°C for pure iron, but only about 1150°C for iron con-

<sup>278</sup> Buchwald 2008, 107-111, 190, 329.

<sup>279</sup> Rathgen 1922, 81; Rathgen 1928, 218, 435-436.

<sup>280</sup> Rathgen 1928, 435.

<sup>281</sup> Rathgen 1928, 162.

<sup>276</sup> Biskup 1966, 89.

<sup>277</sup> Biringuccio, *The Pirotechnia*, Book VII, Chapter 9, p. 319.

taining more than 2% C<sup>282</sup>). It is therefore almost certain that pig iron was purchased for this purpose.

### Conclusions

With regard to gun barrels, a preponderance of copper and its alloys over iron is remarkable. This is especially strongly pronounced in the case of artillery, evidencing that the Order's and municipal authorities were especially concerned about the quality of their cannons. No evidence for manufacture of huge wrought iron cannons in the Teutonic Order's state has been found. This seems to be in stark contrast to some other parts of Europe, where large wrought iron guns were eagerly constructed. With regard to individual non-ferrous metals, there is a slight preponderance of copper over its alloys. On the other hand, all known examples of very heavy cannons were made from bronze. A preponderance of copper alloys could also be assumed for hand-held guns and light artillery in the early 15<sup>th</sup> c. Regrettably, due to the fact that the source basis is much poorer for the second half of the 15<sup>th</sup> c., it would be difficult to say whether the increase in the importance of iron barrels of hand-held firearms after c. 1450 was also the case for the Order's state.

In all probability no experiments with cast iron barrels were made in the Order's state in the late 14<sup>th</sup> and early 15<sup>th</sup> c. This is evidenced by the mention from 1415, which

makes a sharp distinction between iron and cast guns. Therefore, all iron guns used by the Order (at least until the turn of the 15<sup>th</sup> and 16<sup>th</sup> c.) were wrought iron ones.

As regards the technology of manufacture of wrought iron barrels, the Teutonic sources are too laconic to offer any deeper insight into details. On the other hand, as far as cast barrels are concerned, records from the Order's account books and results of archaeological excavations at the castle of Marienburg (Malbork) enable the researcher to link individual stages of manufacture to what is known on gun casting based on Early Renaissance writings and other sources. Furthermore, it is also possible to approximately reconstruct the chemical composition of some cannons. It was found out some lighter cannons in all probability contained more copper (97% or more). On the other hand, light veuglaires and almost all of the largest cannons were cast from metal with a much higher content of tin (11-over 17%). It was perhaps believed that for such guns extra toughness may be needed.

Concerning metal projectiles, it seems that lead was preferred for bullets, although there are also few mentions evidencing the use of iron or even cast iron (projectiles for terrace guns in 1412). On the other hand, cast iron cannonballs in all probability appeared in the Order's state at the turn of the 15<sup>th</sup> and 16<sup>th</sup> c., in line with general European tendencies.

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<sup>282</sup> Buchwald 2005, 63-64, Fig. 57; Buchwald 2008, 245, 303, Fig. 263.

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## Streszczenie

### Technologia produkcji broni palnej w państwie Zakonu Niemieckiego w Prusach – lufy i pociski metalowe

Artykuł analizuje dwa zagadnienia związane z produkcją broni palnej w państwie Zakonu Niemieckiego w Prusach: technologię produkcji luf oraz pocisków metalowych. Wedle źródeł pisanych, wśród surowców stosowanych do wyrobu luf w Prusach było żelazo, brąz i miedź. Niektóre wzmianki źródłowe wymieniają ponadto lufy odlane z bliżej nieokreślonych stopów miedzi. Dane ze źródeł pisanych nie są w pełni reprezentatywne dla całego omawianego okresu (koniec XIV – wczesny XVI w.), jako że najpełniejszym zestawem źródeł dysponujemy jedynie dla przełomu XIV i XV w. Można jednak wyciągnąć kilka wstępnych wniosków. Można zaobserwować przewagę miedzi i jej stopów nad żelazem. Niemal wszystkie najcięższe, znane ze źródeł, działa zostały odlane z brązu. W przeciwieństwie do wielu innych regionów Europy, nie ma informacji o wykonywaniu ciężkich dział ze sztab i obręczy z kutego żelaza w państwie Zakonu w Prusach. Brak także wzmianek o produkcji luf z żelaza lanego. Wskazywać to może, iż większą wagę przywiązywano do jakości, niż do problemu kosztów.

W kwestii szczegółów procesów produkcyjnych, dostępne dane źródłowe dają się powiązać ze stanem wiedzy o technologii odlewania luf armatnich ze stopów miedzi w oparciu o informacje z XVI w. W przeciwieństwie do dotychczas wyrażanych w literaturze poglądów, brak jest informacji o odlewaniu pełnych luf armatnich, które następnie rozwiercano. W niektórych przypadkach udało się wstępnie ocenić (w oparciu o dane dotyczące surowców) skład chemiczny luf armatnich produkowanych przez Zakon ze stopów miedzi. Udział cyny jest najwyższy w przypadku najcięższych dział. Dane te zasadniczo odpowiadają wiedzy z innych źródeł na temat składu chemicznego luf wykonywanych ze stopów miedzi. Niestety niemal brak jest informacji pozwalających na bardziej szczegółową rekonstrukcję technologii produkcji luf żelaznych. Na szczególną uwagę zasługuje wzmianka z 1411 r. o wykorzystaniu osmundu (świeżone lane żelazo, otrzymany w Szwecji we wczesnym procesie wielkopiecowym) do kucia luf broni palnej.

Oдноśnie pocisków metalowych, wydaje się, iż w przeważającej liczbie przypadków wykonywano je z ołowiu. Była to głównie amunicja do ręcznej broni palnej i lekkich dział. Z drugiej strony, kilka wzmianek informuje o produkcji pocisków żelaznych. Najbardziej interesująca z nich dotyczy odlewania amunicji do tarcz w 1412 r. Wydaje się jednak, iż kule działowe z żelaza lanego, które zrewolucjonizowały rozwój artylerii europejskiej, pojawiły się w państwie Zakonu dopiero na przełomie XV i XVI w.

