FORTIFICATION OR ARCHITECTVRE MILITARY.

Vnfolding the principall mysteries thereof, in the resolution of sundry Questions and Problemes.

By R. N.

LONDON,
Printed by *Tho. Cotes*, for *Andrew Crooke*, and are to be sold at the signe of the *Beare* in *Pauls* Church-yard. 1639.

To the Right Honourable, *James* Marquesse of *Hamilton*, Duke of *Chartelraot*, Earle of *Cambridge*, and *Arran*, Lord of *Ennerdale*, *Evendale*, *Arbroth* and *Kenile*, Gent. of the Kings Bed-Chamber, and one of his Majesties most Honorable Privy Counsell, Steward of the Honor of *Hampton-Court* and *Portsmouth*, Great Master of his Maties. horse, and Knight of the most noble Order of the Garter.

Right Honourable,

CONsidering how largely the precepts of *Fortification* are handled by sundry Authors in other languages, and how little is to be found thereof in our English tongue: I thought it neither fruitlesse nor unseasonable, to publish these collections and observations which I had formerly made. Wherein though I chiefly aimed to shew the application of the doctrine of *Triangles*, according to that late invention of *Logarithmes*; Yet have I not pretermitted other things necessary for the better understanding and practise thereof. Which I presume not to present unto your Honour for the worth of it; But in respect of your Lordships knowledge in the *Mathematicks* in generall; and your more speciall experience in *Military* affaires, I am emboldned to crave your Honorable patronage. The Lord of all things and King immortall preserve your Lordship in all happinesse unto his Heavenly kingdome, So prayeth

Your Honors

in all due observance,

Rich. Norwood.

TO THE READER.

WHen I had written the Doctrine of Triangles, suteable to the late Invention of Logarithmes, I endeavoured to make application thereof in sundry parts of the Mathematickes, and amongst the rest in Fortification; Wherein I used the more diligence, that I might give satisfaction to such as I instructed therein. And this was the principall occasion of compiling this ensuing Treatise, which lying by me certaine yeares, I have beene importuned by some friends to publish, for a more common good; whereunto I have the rather yeelded, forasmuch as there is so little extant in our English tongue of this subject. I professe not herein any skill extraordinary; but as it is incident to most men in varietie of studdies, to bend themselves more especially to some one: so I confesse, that although by reason of my Calling (teaching the Mathematickes in London) I have had occasion to apply my selfe to the

the studdy and exercise of sundry Arts Mathemati-call; *Yet more especially to the Optickes, and chiefely to that part thereof which handleth the nature and operation of luminous beames by glasses reflected or refracted, drawne thereunto by a more speciall affection or instinct. All which notwithstanding, I have not beene negligent in this subject, having beene sometimes a souldier in my youth, though not long, and seene some experience of these things, though not much; yet that little with some observations of riper yeares which I since made in the Netherlands, hath somewhat furthered me in handling of it. Besides, I have perused sundry Authors, following those chiefely whom I conceive to have shewed the best rules, and more moderne practise of Fortification. I have endeavoured to be so perspicuous as I could in so many words, avoyding prolixity in this first assay, till I have tryed your entertainement. In the meane time not doubting, but many of our Countrymen, as well such as are here resident, as others applying themselves to the furtherance of our many plantations abroad, will courteously accept this mine endeavour. Farewell.* London. 1637.

FORTI-

FORTIFICATION OR ARCHITECTVRE MILITARIE.

CHAP. I.

BEfore we come to particular Problemes, we will premise some things of more generall use, in all parts of this ensuing Treatise, and first

The proper and more frequent termes of this Art, in *English*, *French*, and *Latine*.

A Fort, French, *Fort*, Latine, *Arx*, *fortalitium*, *munitio*. A Fortresse, a small Fort, or Castle, or Sconce. French *Fortresse*, La. *Castrum muniticuncula*, *munitio Campestris*; these names, a Fort and Fortresse and many of the rest following are (as it may appeare) borrowed of the French; some make a distinction betweene these two names, and would have to be understood by a Fortresse, a little Fort or field Sconce, but others use them promiscuously. The Rampire, this is a wall of Earth enclosing the place fortified, whose foote or foundation is here marked with *a b.* Fre. *Rampart.* Lat. *Vallum.*

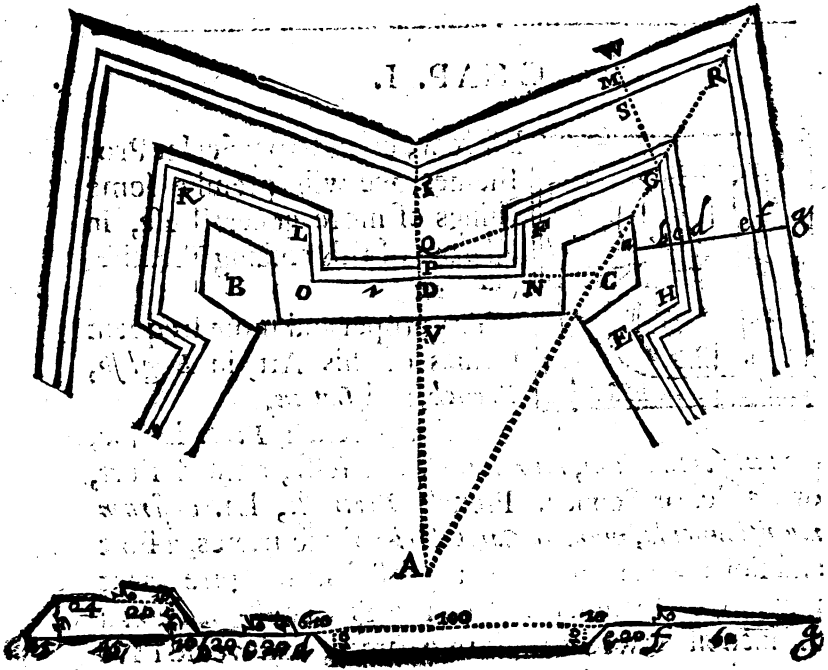
A Curtaine, *O. N.* Fr. *Curtine*, Lat. *Cortina.*

A Bulwarke, *N. F. G. H. E.* Fre. *Bastion, Bauleuert.* Lat. *Propugnaculum.*

The Front of the Bulwarke, *F. G.* Fre. *Face, pand du bastion.* Lat. *Facies propugnaculi.*

The Flancke, *N. F.* Fre. *le Flanc.* Lat. *Ala.*

The Gorge of the Bulwarke, or the space betweene



two flanckes. *N. E.* Fre. *Gorge du bastion*. Lat. *Collum propugnaculi.*

The Gorge line *N. C.* Fr. *ligne du Gorge*. Lat. *linea Colli.*

The Head-line, *C. G.* Fr. *ligne Capitale*. Lat. *Linea capitalis.*

The Shoulder *F*, Fr. *Espaule*. Lat. *Scapula.*

The Diamond point of the Bulwarke, or the flanked angle of the Bulwarke. *G.* Fr. *Angle flanque*. Lat. *Angulus propugnaculi, seu Angulus defensus.*

The second flanke *O. i.* Fr. second *flanc*. Lat. *Ala Cortinæ.*

The fixing fixed, or longest Line of defence *O. G.* Fr. *Ligne de defense fichente*. Lat. *Linea defensionis major.*

The shortest line of defence scowring the front, *i. G.* Fr. *ligne defense flanguante*. Lat. *linea defensionis minor.*

The inward flanking angle, *F. i. N.* Fr. *Angle flanguant interieur*. Lat. *Angulus defensionis interior.*

The outward flanking angle *K. P. G.* Fr. *Angle flanguant exterieur, ou Angle de tenaille*. Lat. *Angulus defensionis exterior.*

A *Casemate*. Fr. *Cazemate*. Lat. *Casa armata.*

The Parapet as namely of the Rampire, Fausebray and Coverat way. Fr. *le Parapet*. Lat. *Lorica.*

The walke on the Rampire. Fr. *Terre-plein*. Lat. *Ambulacrum valli.*

The scarpe, inward or outward, as of the Rampire, parapets and ditch. Fr. *Talud interieur ou exterieur*. Lat. *Acclivitas interior vel exterior.*

Palizadoes. Fr. *Palissades*. Lat. *Sudes præpilatæ.*

A Banke or Foote-pace. Fr. *Banquet*. Lat. *Scamnum, scabellum.*

The Faussebray, the breadth whereof is here marked with *B. C.* Fr. *Cheminées Rondes, Fausse-bray.* Lat. *Spatium horizontale, succinctus.*

The Brimme of the Ditch. Fr. *Lisiere.* Lat. *Margo valli.*

The Ditch, the breadth whereof is here marked with *d. e.* Fr. *le Fosse.* Lat. *Fossa.*

The Counterscarpe. Fr. *Contrescarpe.* Lat. *Acclivitas fossæ exterior.*

The Covert way, the breadth whereof is here marked with *e. f.* Fr. *Corridor, au Chemin covert.* Lat. *via Cooperta.*

A Ravelin. Fr. *Ravelin.* Lat. *Moles.*

An Halfe-moone. Fr. *Demi-lune.* Lat. *Luna dimidiata.*

An Horne-worke, Fr. *Ouvrage à Corne.* Lat. *Opus Cornutum.*

A Trench, Fr. *Trenchee.* Lat. *Seps Castrorum.*

Gabions, Fr. *Gabions.* Lat. *Corbes terræ.*

A Breach, Fr. *Breche.* Lat. *Ruina valli.*

A myne, Fr. *Mine.* Lat. *Cuniculus.*

A Countermine, Fr. *Contremine,* Lat. *Cuniculus reciprocus.*

These and such other tearmes as are used in Fortification will be better understood where we have occasion to speake of them.

The measures used in this ensuing Treatise.

AMong those that write of Fortification, there are severall measures used, as some use feete, and that of severall sizes, some Toises, a toise containing sixe feete, others verges or rods of 12. feete to a verge, which are now generally used in the united Provinces. Wee also in *England*, use rods or poles of severall sizes the most usuall of sixteene feete and an halfe. But of all

all others I should choose (as aptest for this businesse) a Rod of tenne foote, which is also often used by some Architects: For any number of these rods are most easily reduced into feete, and feete into these rods, whereof there is often occasion: Also these rods are most easily reduced into pases, or paces into rods, seeing two make a rod; And paces are such a measure, as every man doth naturally carry about him, at least to a neere scantling, for a man of middle stature walking a travailing pace, moves his foot about one pace, or five foot at each remove, a tall man must goe something slower, and a little man something faster to doe the like, therefore we will here use such rods of tenne feete; and if you make a chaine for this purpose, it may consist of five such rods or 50. feete, which is three of our statute poles and halfe a foote over, and if you would use such a chaine for our ordinary Land measure, you must take up halfe a foote, &c. But this we leave, proceeding to the thing in hand.

CHAP. II.

Axiomes observed in fortification, with the reasons of them.

1 A Fort is made to the intent that a few men might be able to defend themselves and the place, against a greater number.

2. Therefore the place is environed with a Rampire or wall and a ditch, of sufficient height breadth and depth, to impeach the assaults of an enemie.

3. And because the sides thus enclosing a Fort, are not apt for the defence of themselves, especially when an enemy is nearest, and so the defence most necessary, therefore the sides of the Fort have flankers or (as they are commonly called) flankes to defend them, which flankes are also themselves flanked by the Curtaines or sides; these flankes in the foregoing figure are represented by, *H. E.* or *F. N.* or *L. O.* &c.

4. And for the better defence of each side or Curtaine, it is requisite that every side of a Fort should have two flankes, namely toward each end one, and if the side be very long, it may have foure, sixe or more; but of their distance we shall speake hereafter; as of the side *B. C.* the two flankes or flankers are *L. O.* and *F. N.*

5. And thus there will bee two flankes placed neare together at every angle or meeting of two sides, (or oftner if occasion require) the one scowring the side towards the right hand, the other towards the left, either of them standing perpendicular to the sides which they flanke, the distance of which two flankes is called the Gorge or necke of the bulwarke. Two such flankes are represented by *F. N.* and *H. E.* and the Gorge by *N. E.*

6. And because if the wall or Rampire should be continued streight or circuler, betweene the ends of every of these two flankes, thus placed on either side of the Gorge (as from *F.* to *H.*) that wall could not be defended from the flankes, neither is apt for the defence of it selfe: therefore the two Fronts of each bulwarke, are drawne with such inclination, that they might aptly be scoured, and defended from their correspondent flankes. As the Fronts *F. G.* and *G. H.*

7. And seeing the Curtaines and Fronts of a Fort are especially defended, (both with Ordinance and small

shot)

shot) from the Flankes, and that the assailants will soonest attempt to make a breach by battery or otherwise in or about the flanked angle of the bulwarke : therefore the greater and more spacious, the flankes and the Gorge betweene them are (with due consideration of other things considerable) the better they are.

8. And forasmuch as the front of a bulwarke needes the more defence for that it lyes farthest from the flanke defending it, &c. therefore it is so to be drawne that it may be defended by shot from as great a part of the Curtaine as conveniently may be, which part of the Curtaine is called the second flanke; thus in the foregoing figure the second flanke is represented by *O.i.*

9. The outward flanking angle must not be too obtuse namely it should never exceede 150. degrees, but by how much lesse it is, so much the better: for by this meanes, the fronts of the bulwarkes, are the better flanked, the one by the other, &c.

10. And for these two causes chiefely, the angle of the outward or diamond point of a bulwarke should not be greater then 90 degrees. As the angle, *F.G.H.*

11. Yet considering that by how much the more acute that angle of the bulwarke is, so much the weaker it is to withstand a battery, and that the assaults of an enemy by battery are often made against that especially: therefore that angle must never be too acute, namely never lesse than 60. degrees and by how much nearer to a right angle, the better it is. *Errard Barleduc* and some others would have it alwayes a right angle, but by the common practise in the Netherlands, grounded upon sufficient reasons, it is often made lesse.

12. And for the reason aforesayd, the angular point of the figure whereon a bulwarke is to be placed, should

not

not be lesse then a right angle, but by how much the more obtuse, so much the better it is. As the angle *B. C. X.*

13. The inward flancking angle, and the angle of the shoulder of the bulwarke, encrease and decrease together, the one alwayes exceeding the other 90 degrees; and therefore as the inward flanking angle should never be lesse then 15. degrees, so the angle of the shoulder must never be lesse then 105 degrees, and by how much greater, the better, for the same reasons, as are before alleadged. The inward flanking angle is, *F. i. N.* The angle of the shoulder, *G. F. N.*

14. The fixed or longest line of defence drawne from the angle of the flanke to the outward angle of bulwarke should not exceede 720. foote or 72. rodds that so it may not be without musket shot, that being an Engine more portable, and ready for defence then great peeces, which effect nothing but with more losse of time, and other inconveniences. Yet if you will defend the front with Cannon, then may that line be almost twice so much; As a line drawne from *O* to *G.*

15. And for as much as in a regular Fort the force is in all parts more equall and alike; and that it doth enclose a greater quantity of ground, then an Irregular Fort of so many sides: therefore a regular Fort (if the place will conveniently admit of it) is better then an Irregular.

It is called a regular Fort, when the figure fortified consists of equall sides and angles.

16. By that which hath beene sayd, especially by the twelfth axiome, it is evident, that a Fort of three sides, and angles is of no moment, neither is a Fort of foure sides of any great value, but in generall the more sides

and

and angles a Fort hath, the better it is.

17. If the fixed line of defence be 720 foote or 72 roods then may the Curtaine be about 42 rods; the front of the bulwarke may be about 28 rods; and the angle forming the flanke about 40 degrees, and the flanke to the Gorge as 6. to 7. But if the figure you would fortifie be lesse, you may diminish the gorges, flankes, and fronts, proportionally retaining the angles sutable to these Axiomes, and hereafter more particularly expressed. And in fortifying any place, regular or irregular, you are to observe (so neere as may be) these Axiomes, and the reasons of them together with the Problemes and examples, hence deduced, and hereafter set downe. The angle forming the flanke is *F. C. N.*

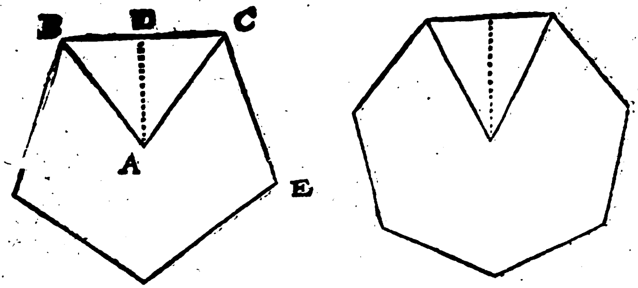
CHAP. III.

PROBLEME. I.

TO finde the quantity of the angle, at the Center or perimeter of any regular poligon and the number of inhabitants whereof a fort is capable as in this figure, following let *B C.* be the side of an Equilaterall pentagon

There is required the angle at the Center *B. A. C.* and the angle at the perimeter, *B. C E.* Divide the circumference of a circle, 360. degrees, by the number of the sides of the poligonon, 5. the quotient is the angle at the Center, *B. A. C.* 72. degrees. which substracted from 180. degrees, there remaines the angle at the

perime-



perimeter, *B. C. E.* 108. degrees.

The reason of the first part of this operation is manifest, and touching the second, seeing the th[illegible]ee angles of the triangle, *A. B. C.* are equall to 180. degrees therefore from 180. degrees substracting the angle *B.A.C.* there remaines the sum of the angles *A.B.C.* and *A.C.B.* which two being severally the half of the angles at *B.* and *C.* are together eq[illegible]all to the angle *B.C.E.*

PROBLEME. 2.

The Quantity of one of the sides given: to fi[illegible]de the semidiameter of the circumscribed Circle, and the perpendiculer to that side and so the area or quantity of ground in that figure.

AS in the foregoing figure, let the side of a pentagonall Fort *B. C.* be after the *Italian* manner 800. foote, then is the halfe thereof *B. D.* 400. foote, and the angle at the center, *B. A. C.* 72. degrees, the halfe whereof is *B. A. D.* 36. degrees. and the complement thereof *D.B.A.* 54. degrees, therefore by the first case of plaine ttiangles,

As

As *Radius* is in proportion	
to halfe the side given	*BD*, 400. foote 2, 6020600.
so tang halfe the angle at the perimeter	*t ABC* 54--06. 10, 1387390.
to the perpendiculer	*AD* 550. 55, 2, 7407990.

And by the second case of plaine triangles,

As sine halfe the angle at the center	*s. BAD* 36--06, 2307813.
to halfe the side given	*BD* 400. foote 2, 6020600.
So is *Radius*	
to the semidiameter of the Poligon	*AB*, 680. 52-- 2, 8328413

This is more properly the semidiameter of the circumscribed circle which for brevity sake we call here and hereafter the semidiameter of the poligonon.

This perpendiculer	*AD*. 550. 55. 2, 7407990.
multiplyed by halfe the base	*BD*. 400. . 2, 6020600.
produceth the area of the triangle	*ABC*. 220221. 5, 3428590.
which multiplyed by the number of sides	. 5. 0, 6989700.
produceth the area of the poligonon	1101105. f. 6, 0416260.

Note. The operations here or hereafter used by logarithmes whether in the resolution of triangles or in multiplication, division, extraction of rootes or the rule of proportion I have sufficiently handled in my first booke of plaine triangles which therefore it were superfluous here to repeate, the fractions here and hereafter used are decimals namely tenth or hundreth parts: so that if there be one figure behind the pricke it signifies tenths as 351. 2 is 351 $\frac{2}{10}$. so 550. 55. is 550 $\frac{55}{100}$.

Probleme. 3.

To finde what number of inhabitants a Fort is capable of.

IT is to be understood that within the poligon figure cast up as we have shewed in the last Probleme, there is the Rampire, the streets, the Market place, and the residue for the inhabitants; now the Rampire, streets & Market place may be the halfe or third part of the area of the poligon figure, sometimes more sometimes lesse, and that being substracted the residue (as I say) is for the inhabitants. We will take for example the seven sided Fort expressed hereafter in the 11. Chapter.

I devide the circumference of a Circle, 360. deg.
by the number of sides which is 7.
the quotient is the angle at the Center *BAC*. 51. 25 $\frac{5}{7}$.
which substracted from 180. deg.
remaine the angle at the perimeter *BCE*. 128. 34 $\frac{2}{7}$.
And supposing the side of the poligon namely the curtaine with the two Gorge-lines to be 702. 4.

Then will the perpendiculer be found by the last Probleme to be about 729. foote, so that the area of the triangle *B. A. C.* will be 256025. square feete and seeing the figure hath 7. sides therefore the area of the whole poligon figure is 1792175. square feete, Now we suppose the Rampire to be there 70 foote broade, and the streete or way next within the Rampire 40. foote, both are 110. foote which substracted from the foresayd perpendicular 729. there remaines a perpendicular, 619. then forasmuch as like poligon figures are in double the proportion of their proportionall sides,

therefore

therefore

As the square of the perpendiculer 729		7,1372725. / 7,1372725.
To the square of the perpendiculer 619		2,7916906. / 2,7916906.
So is the first area	1792175.	6,2533800.
to the second area	1292130.	6,1113062.

Or if you rather desire to work by triangles then supposing the perpendicular to be *A. D.* 619. you must finde halfe the side *B. D.* saying

As *Radius* is in proportion		
to the perpendicular	*AD.* 619.	2,7916906.
so tan. half the an. at h' cen. t *BAD.*	25 42.	9,6828270.
to halfe the side,	*BD.* 298.21.	2,4745176.
which mult. by the perp.	*AD.* 619.	2,7916906.
produceth the area of	*BAC.* 184590.	5,2662082.
Which againe multiplyed by he sides	7.	0,8450980.
produceth the 2d area	1292130.	6,1113062.

And so much is this heptagon within the Rampire, and the streete going round within the Rampire.

Next for the Market place, the side thereof being 170. foote.

As halfe the side of the Fort,	351. 2.	7,4544455.
to half the side of the Market pla.	85.	1,9294189.
so is the perpend. of the Fort	729.	2,8627276.
to the perp. of the Market place	176.44.	2,2465920.
which multip. by halfe the side	85.	1,9294189.
and that againe by all the sides	7.	0,8450980.
prod. the area of the Market pla.	104982.	5,0211089.

 and

and ſeeing the one perpendiculer is	619. foote.
and the other of the Market place	176.44.
the difference of theſe two is	442.56.

∴ Being the diſtance from the Market place, to the ſtreete next under the Rampire,

which multiplyed by the breadth	30. foote.
produ. the area of one of thoſe ſtreets	13276.80.
which multipl. by the number of ſides	7.
produceth the area of all thoſe ſtreets	92937.

Laſtly for the middle ſtreete that goeth round about betweene the Rampire and the Market place.

Let us ſuppoſe in this example the perpendiculer diſtance of that ſtreete from the center of the Market place to be 42 rods, (I meane from the center of the Fort to the middle line of that ſtreete) then for a ſeventh part of the middle perimeter or compaſſe of that ſtreete I ſay.

As the firſt perpendiculer	729. foote.		7,1372725.
to this perpendiculer,	420. foote.		2,6232493.
ſo the firſt ſide,	702.	4.	2,8465845.
to this ſecond ſide	404.	67.	2,6071063.
which multiplyed by	7.		0,8450980.
prod. the compa. of that ſtreet	2832.	7.	3,4522043.
which mul. by the breadth	30.		1,4771213.
prod. the area of that ſtreet,	84982.		4,9293256.
and the area of the other 7. ſtr.	92937.		
and the area of the market place,	104982.		
The ſumme of theſe three	282901.		ſquare feete.
ſubſtr. from the before found	1292130.		
there remaines	1009229.		ſquare feete.

Thus

Thus then the heptagon to be fortified containes as before wee found 1792175. square feete, but within the Rampire and the streete or way next within the Rampire it containes but 1292130 square feete whereof the streetes and market place, amount to 282901. square feete which deducted there remaines for the houses and other accommodations of the inhabitants, 1009229. square feete that is 10092 rods and 29 feete square. Now we may asigne for every house 10 square rods or 1000. square feete, or something more or lesse as the present occasion shall require; and so this place is capable of 1009 housholds for deviding 1009229 feete by 1000, or 10092 rods by 10, the quotient in either is 1009. besides the fraction which here we regard not.

CHAP. IIII.

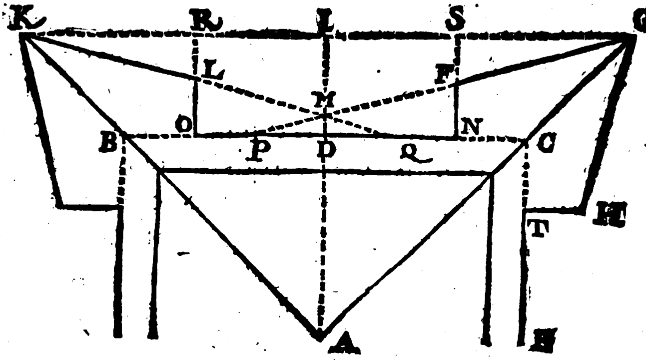
To finde the quantity of the angles in all parts of a Fort of any number of sides proposed.

BY the sixteenth Axiome, a Fort is to consist of at least foure sides, and by the eleventh Axiome, the flanked angle of a bulwarke ought to be at the least 60. degrees, therefore in a regular Fort of foure sides, the flanked angle of each bulwarke ought to be 60. degrees, and consequently the outward flanking angle must needes be 150 degrees.

As in this figure let *B. C.* be one side of a square fortified with foure bulwarkes, one of which let bee

N. F. G.

N.F.G.H.T. And seeing the flanked angle of this Bulwark *F.G.H.* is 60. degrees, therefore the halfe thereof



F.G.C. is 30. degrees, and *I.G.C.* (being equall to *D.C.A.* namely halfe the angle of the tetragon) is 45. degrees, therefore *S.G.F.* is 15. degrees, and the complement thereof *S.F.G.* 75. degrees, whereto is equall the angle *I.M.G.* which is the halfe of *K.M.G.* therefore the outward flanking angle, *K.M.G.* is 150. degrees, which was to be proved.

And thus in a quadrangular Fort, the flanked angle is 60. degrees, and the outward flanking angle 150. degrees; what these angles will be in other Forts consisting of more sides we may finde by helpe of these thus.

Substract the angle of the square namely 90. degrees from the angle of the poligonon proposed, halfe the remainer adde to the flanked angle of the square that is to 60. degrees, and so you have the flanked angle of the poligon proposed: Also substract the foresayd halfe remainer from the flanking angle of the square, namely from 150. degrees, and that which remaines is the flanking angle of the poligonon proposed.

I. *Exam-*

1. *Example of a Pentagon.*

The anglē at the perimeter is	180.d.
from which ſubſtr. the angle of the ſquare,	90.
there remaines	18.
the halfe whereof	9.
added to the flanked angle of the ſquare	60.d.
gives the flanked angle of the pentagon	69.
And from the flanking angle of the ſquare,	150.d.
ſubſtracting the aforeſayd	9.
remaines the flanking angle of the pentagon,	141.

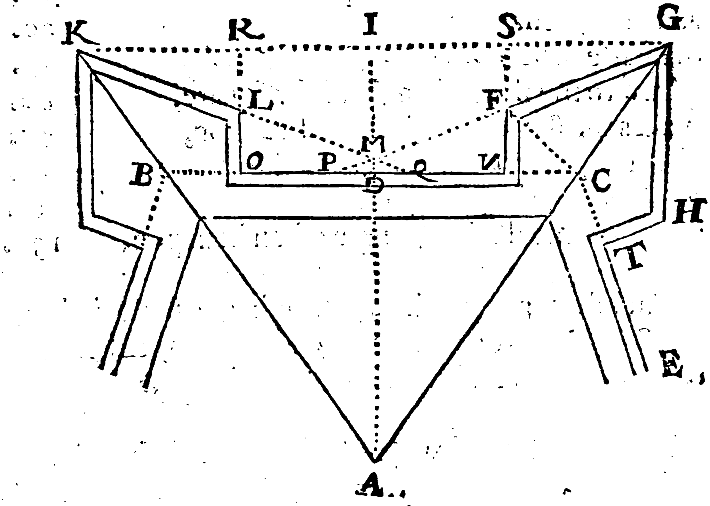
2. *Example of a Hexagon.*

From the anglē of the hexagon being,	120.d.
ſubſtract the angle of the ſquare,	90.
and there remaines	30.
the halfe whereof	15.
added to the flanked angle of the ſquare,	60.
makes the flanked angle of an hexagon,	75.
and from the flanking angle of the ſquare	150.
ſubſtracting the foreſayd,	15.
remaines the flanking angle of an hexagon,	135.

And thus proceeding in the uſe we ſhall finde that the flanked angle will not be *90.* degrees, till we come to a Fort of twelve ſides.

Now the flanked angle of a bulwarke being given we may thereby come to the knowledge of all the other angles requiſite to be knowne,

As in this figure let *B C* be the side of a Pentagon, whose angle at the Center is (by the 1. ch.	*B A C*. 72. d. 06.
the half whereof is	*C A D*. 36. 00.
the complement thereof,	*D C A*. 54. 00.
now admit the angle of the bulwark,	*F G H*. 69. 00.
the halfe thereof	*F G C*. 34. 30.
substracted from *S G C* being equall to	*D C A*. 54. 00.
remaines the inward flanking angle	*S G F*. 19. 30.
equall to *F P N* the compl. of either	*S F G*. 70. 30.
substracted from two right angles,	180. 00.
leaves the angle of the shoulder	*N F G*. 109. 30.
Againe the same angle *S F G* or	*I M G*. 70. 30.
doubled, gives the outward flan. ang.	*K M G*. 141. 00.
Lastly from two right angles,	180. 00.
substr. half the angle of the poligon,	*B C A*. 54. 00.
remaines the angle,	*D G G*. 126. 00.



And

But if you would have the flanked angle of the Bulworke so to encrease, that for an Octagon it might be a right angle, then make the flanked angle, two third parts of the angle of the poligon proposed, as is done in the Table following, but for any poligon of above eight sides, let the flanked angle be a right angle.

A Table of the dimensions of the angles observed in Fortifying any Regular Poligon from the Tetragon to the Octagon, so increasing that the flanked angle of the Octagon is a right angle.

Poligons the number of their sides	4	5	6	7	8
	deg.	deg.	deg	deg.	deg.
Angle at the Center ——— B A C.	90	72	60	$51\frac{3}{7}$	45
halfe the angle at the Center — I A G.	45	36	30	$25\frac{5}{7}$	$22\frac{1}{2}$
the angle of the Poligon — B C E.	90	108	120	$128\frac{4}{7}$	135
the flanked angle ——— F G H.	60	72	80	$85\frac{5}{7}$	90
halfe the angle of the Poligon — B C A.	45	54	60	$64\frac{2}{7}$	$67\frac{1}{2}$
halfe the flanked angle — F G C.	30	36	40	$42\frac{6}{7}$	45
the inward flanking angle — S G F.	15	18	20	$21\frac{3}{7}$	$22\frac{1}{2}$
to which adding a right angle ———	90	90	90	90	90
the angle of the shoulder — N F G.	105	108	110	$111\frac{3}{7}$	$112\frac{1}{2}$
the angle opposite to the head-line G F C.	55	58	60	$61\frac{3}{7}$	$62\frac{1}{2}$
the angle opposite to the front — F C G.	95	86	80	$75\frac{1}{7}$	$72\frac{1}{2}$
the compl. of S G F. *namely* — S F G.	75	72	70	$68\frac{4}{7}$	$67\frac{1}{2}$
the outward flanking angle — K M G.	150	144	140	$137\frac{1}{7}$	135
the angle forming the flanke — F C N.	40	40	40	40	40

A Table of the dimensions of the angles observed in fortifying any regular Poligon from the Square, to a figure of 12. sides, so increasing that the flanked angle thereof is a right angle.

Poligons the number of their sides	4	5	6	7	8	9	10	11	12
	deg.	deg.	deg.	deg.	deg.	deg.	deg.	deg.	deg.
Angle at the Center —— BAC.	90	72	60	$51\frac{3}{7}$	45	40	36	$32\frac{8}{11}$	30
Angle of the Poligon —— BCE.	90	108	120	$128\frac{4}{7}$	135	140	144	$147\frac{3}{11}$	150
halfe the angle of the poligon —— BCA.	45	54	60	$64\frac{2}{7}$	$67\frac{1}{2}$	70	72	$73\frac{7}{11}$	75
whereunto adde ——	15	15	15	15	15	15	15	15	15
The flanked angle —— FGH.	60	69	75	$79\frac{2}{7}$	$82\frac{1}{2}$	85	87	$88\frac{7}{11}$	90
halfe the flanked angle —— FGC.	30	$34\frac{1}{2}$	$37\frac{1}{2}$	$39\frac{9}{14}$	$41\frac{1}{4}$	$42\frac{1}{2}$	$43\frac{1}{2}$	$44\frac{7}{22}$	45
Inward flanking angle FPN. *or* SGF.	15	$19\frac{1}{2}$	$22\frac{1}{2}$	$24\frac{5}{14}$	$26\frac{1}{4}$	$27\frac{1}{2}$	$28\frac{1}{2}$	$29\frac{7}{22}$	30
which added to a right angle ——	90	90	90	90	90	90	90	90	90
Angle of the shoulder —— NFG.	105	$109\frac{1}{2}$	$112\frac{1}{2}$	$114\frac{9}{14}$	$116\frac{1}{4}$	$117\frac{1}{2}$	$118\frac{1}{2}$	$119\frac{7}{22}$	120
Angle opposite to the head-line GFC.	55	$59\frac{1}{2}$	$62\frac{1}{2}$	$64\frac{9}{14}$	$66\frac{1}{4}$	$67\frac{1}{2}$	$68\frac{1}{2}$	$69\frac{7}{22}$	70
Angle opposite to the front —— FCG.	95	86	80	$75\frac{5}{7}$	$72\frac{1}{2}$	70	68	$66\frac{4}{11}$	65
the complement of SGF. *namely* SFG.	75	$70\frac{1}{2}$	$67\frac{1}{2}$	$65\frac{5}{14}$	$63\frac{3}{4}$	$62\frac{1}{2}$	$61\frac{1}{2}$	$60\frac{15}{22}$	60
the outward flanking angle —— KMG.	150	141	135	$130\frac{5}{7}$	$127\frac{1}{2}$	125	123	$121\frac{4}{11}$	120
the angle forming the flanke —— FCN.	40	40	40	40	40	40	40	40	40

And thus for any flanked angle proposed wee may finde the quantities of every of the other angles.

But for any poligon proposed wee may more compendiously set downe the angles of the bulwarkes and all the other angles after the forme of this example following, remembring that if the poligon have more than 12. sides, you make the angle of the bulwarke a right angle.

		d.
To half the angle of the poligon	*B C A.*	54. 00.
adde alwayes		15. 00.
the summe is the flancked angle	*F G H.*	69. 00.
the halfe whereof	*F G C.*	34. 30.
substr. from half the angle of the polig.	*B C A.*	54. 00.
leaves the inward flanking angle,	*S G F.*	19. 30.
whose complement is	*S F G.*	70. 30.
which substracted from two right angles,		180. 00.
leaves the angle of the shoulder	*G F N.*	109. 30.
and the same complement *S F G* or	*I M G.*	70. 30.
doubled is the outward flanking angle.	*K M G.*	141. 00.

The angle forming the flanke, namely the angle *F. C. N.* may be alwayes about 40 degrees. And according to this rule is the table following made.

CHAP. V.

Of the quantitie of the Curtaines, Flankes, Fronts, Gorges, and other sides and lines in regular Forts of any number of sides proposed.

IT is not of necessity that the angles in Forts should be exactly such as are found and set downe by the foregoing Rule, but they may be something more or lesse, as the place or other occasions shall require: But first supposing them to be such, we will shew how to determine the quantity of the sides and lines of a Fort accordingly both by examples and tables for that purpose.

Probleme. I.

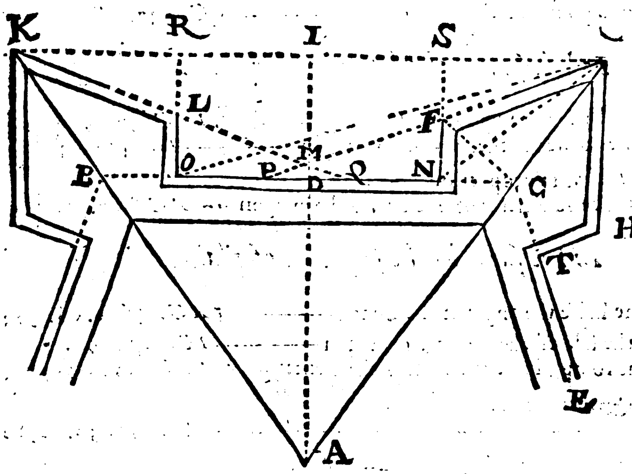
The length of the Curtaine, and of the Front of the Bulwarke given, to finde what the other sides and lines should be.

AS in this regular Pentagonall Fort, and so in others, to the intent the line of defence may be about 72. rods the Curtaine may be about 42. rods and the Front about 28. as is before noted in the 17. Axiome. And that the proportion of the flanke to the Gorge may bee about 6. to 7. let the angle forming the flanke bee 40. degrees.

Thus then the Curtaine is *O N*. 420. foote.
the Front of the Bulwarke *F G*. 280. foote.

And

And the angle forming the Flankē — FCN. 40. deg.
And let the Flanked angle be — FGH. 69. deg.



Then will the other angles be found by the first rule of the foregoing chapter to be such as are expressed in the former of the two tables: but the sides we finde thus.

In the right angled triangle SGF. *by 3. case of plaine triangles I say.*

As *Radius* is in proportion
to the front of the Bulwarke ———————— *F G*. 280 feete 2,44715.
so sine the inward flanking angle ———— *s. S G F*. 19. deg. 36. 9.52350.
to the line ———————— ———————— *S F*. 93. 47. 1,97065.

Againe by the same.

As *Radius* is in proportion
to the front of the bulwarke ——————— *F G*. 280. feete. 2,44725.
so sine compl. the inward flanking angle — *s. c. S G F*. 19. deg. 30. 9,97435.
to the line ————————————— *S G*. 263. 94. 2,42150.
Whereto adding halfe the Curtaine ———— *S I*. 210.

the summe is the line	I G. 473. 94.	
which doubled is the side of the outward poligonon, or the distance of diamond points of the bulwarkes	K G. 947. 88.	

In I A G. by the second case of plaine triangles.

As sine halfe the angle at the Center	s. I A G. 36. d. 06.	,23078.
to halfe the side of the outward pentagon	I G. 473. 94.	2,67572
So is Radius in proportion		
to the Semidiameter of the outward pentagon	A G. 866. 31.	2,90650

In the same by the first case of plaine triangles.

As sine halfe the angle at the Center	s. I A G. 36. d. 06.	,23078.
to ½ the side of the outward pentagon	I G. 473. 94.	2,67572.
so sine compl. halfe the angle at the Center	s. c. I A G. 36. 00.	9,90796.
to the perpendicular of the outward pentagon	A I. 652. 32.	2,81446.

In F C G. by the eighth case of plaine triangles.

As the sine of the angle	s. F C G. 86. d. 06.	,00106.
is in proportion to the Front	F G. 280.	2,44715.
so sine halfe the flanked angle	s. F G C. 34. 36.	9,75313.
to the line	F C. 158.98.	2,20134.

In the same triangle F C G. by the same case.

As the sine of the angle	s. F C G. 86. d. 06.	1,00106.
is in proport. to the front	F G. 280.	2,44715.
so is the sine of the angle	s. G F C. 59. 36.	9,93532.
to the head line	C G. 241. 84.	2,38353.
which substracted from the semidiam.	A G. 806. 31.	
there remaines the semidiameter of the inward pentagon	A C. 564. 47.	

In the triangle F C N. by the third case.

As Radius is in proportion		
to the line before found	F C. 158. 98.	2,20134.
so sine the angle forming the flanke	s. F C N. 40. 06.	9,80807.
to the flanke	F N. 102. 19.	2,00941.

whereto

whereto adding the line first found —— S F. 93. 47.
we have the distance of the pentagons s N or —— I D. 195. 66.
which substracted from the perpendicular —— A I. 652. 32.
there remaines the perpendicular of the
inward pentagon —— A D. 456. 66.

In the triangle FNC by the third case.

As *Radius* is in proportion
to the line before found —— F C. 158. 98. 2,20134.
so sine compl. the angle forming the flanke —— s.c. FCN. 40. d. 00 9,88425.
to the Gorge line —— N C. 121. 78. 2,08559.
whereto adding halfe the Curtaine —— D N. 210.
we have the line —— D C. 331. 78.
which doubled is the side of the inward
pentagon —— B C. 663. 56.

In the triangle FPN. by the first case.

As sine the inward flanking angle —— s. F P N. 19. d. 36. —, 47650.
is in proportion to the flanke —— F N. 102. 19. —— 2,00941.
so sine compl. the inward flank. angle —— s. c. F P N. 70. 36. — 9,97435.
to the line —— P N. 288. 58. —— 2,46026.
which substract from the Curtaine —— O N. 420.
remaines the second flanke —— O P. 131. 42.

In the triangle ROG. by the fifth case.

To the line before found —— S G. 263. 94.
Adding the Curtaine —— O N. 420.
we have the line —— R G. 683. 94.

First.

As the line R O or —— I D. 195. 66. 7,70850.
is to that line —— R G. 683. 94. 2,83502.
so is *Radius* in proportion
to the tang. of the angle —— t. R O G. 74 — 62. 10,54352

Secondly.

As the sine of that angle —— s. R O G. 74. d. 62 —, 01709.
is in proportion to the line —— R G. 683. 94. —— 2,83502.
so is *Radius* in proportion
to the longest line of defence —— O G. 711. 4. —— 2,85211.

In

In like sort we might finde the distances DM. PM *&c.*

Touching the fractions in this and all other examples they are as we have before sayd decimall so as the number before the pricke signifies so many integers, the figure behind the pricke, so many tenths of a unite as 711.4. *last before signifies* 711 $\frac{4}{10}$ *feete, so* 711.41. *signifies* 711 $\frac{41}{100}$ *and the like is to be understood of all others.*

2. *Example.*

In the same pentagonall figure, let these parts be as before,
namely the Curtaine ———— *O N.* 420. foote.
the front of the bulwarke ———— *F G.* 280.
the angle forming the flanke ———— *F C N.* 40.d.
and let the flanked angle of the bulwarke be ———— *F G H* 72.d.

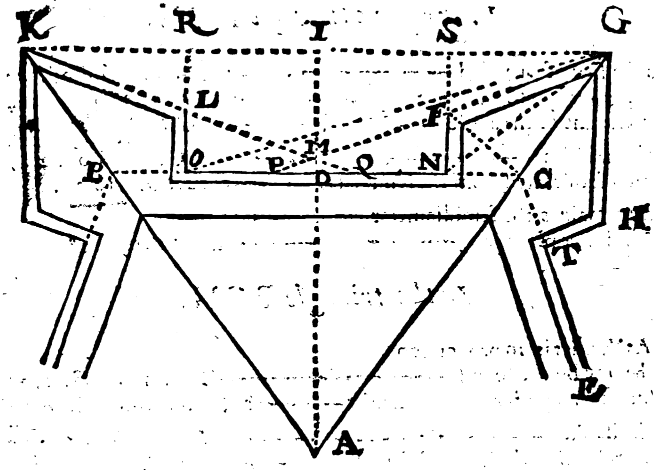
Then will the other angles be found by the second rule of the foregoing chapter to be such as are there expressed in the latter of the two tables, and the sides we finde as before, in the triangle SGF.

As *Radius* is in proportion
to the front of the bulwarke ———— *F G.* 280. foote. 2,44715.
so sine the inward flanking angle ———— *s. S G F.* 18.d.60. 9,48998.
to the line ———— *SF.* 86.52. 1,93713.

In the same triangle SGF.

As *Radius* is in proportion
to the front of the bulwarke ———— *F G.* 280. 2,44715.
So sine compl. the inward flanking angle — *s. c. S G F.* 18 — 06. 9,97821.
to the line ———— *S G* 266.29 — 2,42536.
whereunto addding halfe the Curtaine ———— *S I.* 210.
the summe is the line ———— *I G.* 476. 29.
which doubled is the distance of the angular
points of the bulwarkes ———— *K G.* 952.58.

In



In the triangle IAG.

As sine halfe the angle at the center —— s. *IAG*. 36. d. 06. —— 9,23078.
to halfe the side of the outward pentagon —— *IG*. 476,29. —— 2,67787.
So is *Radius* in proportion to the
Semidiameter of the outward pentagon —— *AG*. 810. 31. — 2,90865.

In the same triangles

As sine halfe the angle at the center —— s. *IAG*. 36. d. 06. 9,23078.
to ½ the side of the outward pentagon —— *IG* 476. 29. 2,67787.
so sine compl. halfe the angle at the center — s. c. *IAG*. 36. 06. 9,90796.
to the greater perpendiculer —— *AI*. 655. 56. 2,81661.

In the triangle FCG.

As the sine of the angle —— s. *FCG*. 86 d. 06. 9,99896.
is in proportion to the Front —— *FG*. 280. — 2,44715.
so sine halfe the flanked angle —— s. *FGC*. 36. 06. 9,76922.
to the line —— *FC*. 164 98. 2,21741.

In the same triangle FCG.

As the sine of the angle —— s, F C G. 86.d.06. 00106.
is in proportion to the front —— F G. 280. —— 2,44715.
so is the sine of the angle —— s. G F C. 58.00. 9,92842.
to the head-line —— CG. 238.03. 2,37663.
Which substracted from the semidiam. —— A G. 810.31.
there remaines the semidiameter
of the inner pentagon —— A C. 572. 28.

In the triangle FCN.

As Radius is in proportion
to the line before found —— F C. 164. 98. 2,21743.
so sine the angle forming the flanke —— s. F C N. 40.d.06. 9,80807.
to the flanke —— F N. 106. 05. 2,02550.
whereto adding the line first found —— S.F. 86. 52.
we have the distance of the pentag. S N or —— I D. 192. 57.
which substracted from the perpendicular —— A I. 655. 56.
leaves the perpend. of the inward pentagon —— A D. 462. 99.

In the triangle FNC.

As Radius is in proportion
to the line before found —— F C. 164. 98. 2,21743.
so sine comp. the angle forming the flanke —— s.c. F C N. 40.d.06. 9,88425.
to the Gorge line —— N C. 126. 38. 2,10168.
whereunto adding halfe the curtaine —— D N. 210.
summe is the line —— D C. 336. 38.
which doubled is the side of the inward
pentagon —— B C. 672. 76.

In the triangle FPN.

As sine the inward flanking angle —— s. F P N. 18.d.06. 0,51002.
is in proportion to the flanke —— F N. 106. 05. 2,02550.
so sine comp. the inward flanking angle —— s. c. F P N. 18.00. 9,97821.
to the line —— P N. 326.39. 2,51373.
which substracted from the curtaine —— O N. 420.
remaines the second flanke —— O P. 93.61.

In the triangle R O G.

To the sine before found ————————— *S G.* 266. 29.
adding the curtaine ————————— *O N.* 420.
we have the line ————————— *R G.* 686. 29

then

As the line *R O* or ————————— *I D.* 192. 57. 7,72541.
is to that line ————————— *R G.* 686. 29. 2, 83651.
so is *Radius* in proportion
to the tangent of the angle ————————— *t. R O G.* 74. d. 20′. 10, 55192.

Secondly.

As the sine of that angle ————————— *s. R O G.* 74. d. 26. 9,01646.
is in proportion to the line ————————— *R G.* 686. 29. 2,83651.
so is *Radius* in proportion
to the longest line of defence ————————— *O G.* 712. 80. 2,85297.

3. *Example.*

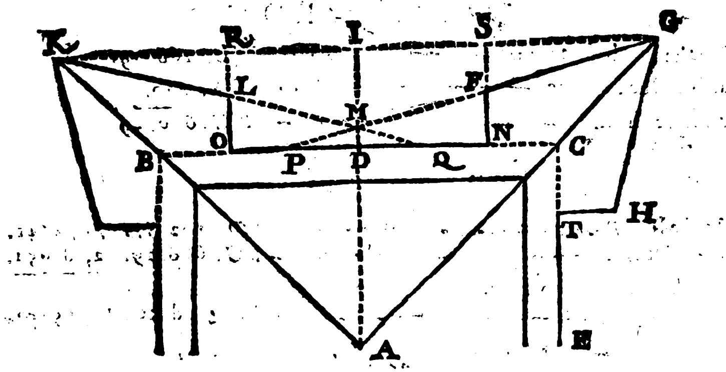
In this Tetragonall or Quadrangular Fort following
Let the length of the Curtaine be O N. 42. r. *or* 420. f.
the front of the bulworke be F G. 28. r. *or* 280. f.
the angle forming the flanke F C N. 40. d. 06.
the flanked angle of the bulworke F G H. 60. d. 00.

Then will the other angles be found by either of the rules *Chapter* 4. to be such as are expressed in either of the two tables there: and for finding the sides we proceed as before thus.

In the triangle S G F.

As *Radius* is in proportion
to the front of the bulworke ————————— *F G.* 280. foote. 2,44715.
so sine the inward flanking angle ————————— *s. S G F.* 15. d. 06. 9. 41300.
to the line ————————— *S F.* 72. 47. — 1,86015.

 In



In the same triangle SGF.

As Radius is in proportion
to the front of the bulwarke ———— *FG*. 280. foote. 2, 44715.
so sine comp. the inward flanking angle —— s. c. *SGF*. 15. 00. 9, 98494.
to the line ———— *SG*. 270. 45. 2, 43209.
whereunto adding halfe the Curtaine ———— *SI*. 210.
the summe is the line ———— *IG*. 480. 45.
which doubled is the side of the outward
tetragon ———— *KG*. 960. 90.

In the triangle IAG.

As sine halfe the angle at the center ———— s. *IAG*. 45. d. 06. 0. 15051.
to halfe the side of the outward tetragon ———— *IG*. 480. 45. 2,68165.
So is *Radius* in proportion to the
semidiameter of the outward tetragon ———— *AG*. 679. 46. 2, 83216.

In the same triangle.

As sine halfe the angle at the center ———— s. *IAG*. 45. 06. 0, 15051.
to halfe the side of the outward tetragon ———— *IG*. 480. 45. 2, 68165.
so sine compl. halfe the angle at the center —— s. c. *IAG*. 45. 00. 9, 84949.
to the greater perpendiculer ———— *AI*. 480. 45. 2,68165.

In

In the triangle FCG.

As the sine of the angle ——— s. *FCG*. 95. d. 06. 0,00166.
is in proportion to the front ——— *FG*. 280. — 2,44715.
so sine halfe the flanked angle ——— s. *FGC*. 30. d. 06. 9.69897.
to the line ——— *F*. . 140. 53. 2,14778.

In the same triangle FCG.

As the sine of the angle ——— s. *FCG*. 95. 06. d. 0,00166.
is in proportion to the front ——— *FG*. 280. — 2,44715.
so is the sine of the angle ——— s. *GFC*. 55. d. 06. 9.91336.
to the head line ——— *CG*. 230. 23. 2,36217.
which taken from the greater semidiameter ——— *AG*. 670. 46.
remaines the lesser semidiameter ——— *AC*. 449. 23.

In the triangle FCN.

As *Radius* is in proportion
to the line before found ——— *FC*. 140. d. 53'. 2, 14778.
so sine the angle forming the flanke ——— s. *FCN*. 40. d. 00. 9,80807.
to the flanke ——— *FN*. 90. 33. 1.95585.
whereunto adding the line first found ——— *SF*. 72. 47.
we have the distance of the two tetrag. — *KG* and *BC*. 162. 80.
which substracted from the perpend. ——— *AI*. 480. 45.
there remaines the perpendiculer of
the inward tetragon ——— *AD*. 317. 65.

In the triangle FNC.

As *Radius* is in proportion
to the line before found ——— *FC*. 140. 53. 2,14778.
so sine compl. the angle forming the flanke — s. c. *FCN*. 40. d. 06. 9,88425.
to the Gorge line ——— *NC*. 107. 66. 2,03203.
whereunto adding halfe the curtaine ——— *DN*. 210.
we have the line ——— *DC*. 317. 66.
which doubled is the side of the inward
tetragon ——— *BC*. 635. 32.

In the triangle FPN.

As sine the inward flanking angle	s. *F P N.* 15.d. 06.	0,58700.
is in proportion to the flanke	*F N.* 90. 33.	1,95585.
so sine compl. the inward flanking angle	s. c. *F P N.* 15. 00.	9,98494.
to the line	*P N.* 337. 13.	2,52779.
which substracted from the curtaine	*O N.* 420.	
remaines the second flanke	*O P.* 82,87.	

In the triangle ROG.

To the line before found	*S G.* 270. 45.
adding the curtaine	*O N.* 420.
summe is the line	*R G.* 690.45.

First.

As the line *R O* or	*I D.* 162. 80.	7,78835.
is in proportion to the line	*R G.* 690. 45.	2,83913.
so is *Radius* in proportion to the tangent of the angle	t. *R O G.* 76.d. 44'.	10,62748.

Secondly.

As the sine of that angle	s. *R O G.* 76.d. 44'.	0, 01175.
is in proportion to the line	*R G.* 690. 45.	2, 83913.
so is *Radius* in proportion to the fixed or longest line of defence	*O G.* 709. 42.	2, 85090.

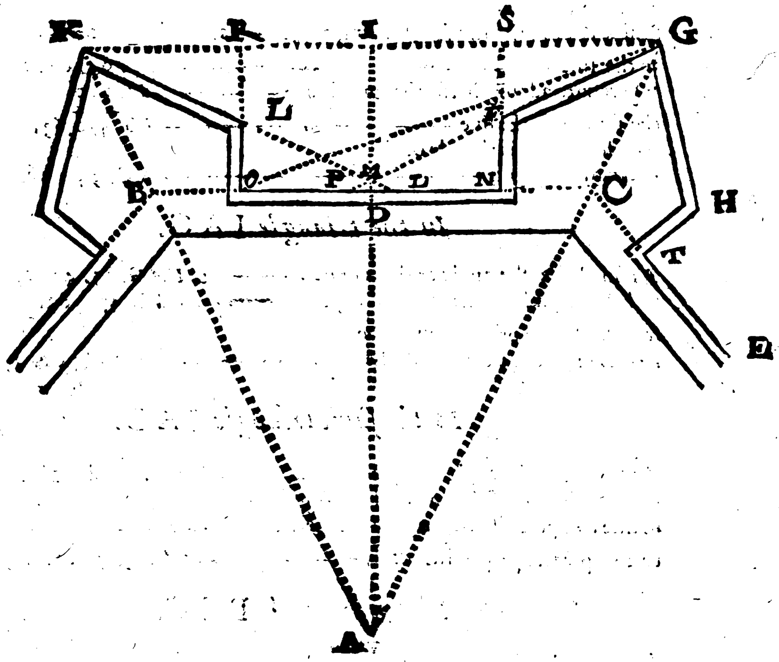
4. *Example.*

Let there be a heptagon or figure of seven sides to be fortified with bulworkes, &c.

Let the length of the curtaine be	ON. 420. foote
the front of the bulwarke	FG. 280.
the angle of the bulwarke	FGH. 85.d. 43'.

Then will the other angles be according to the second

cond rule and second table of the fourth Chap. and for finding the sides we proceede as before saying.



In the triangle S G F.

As *Radius* is in proportion		
to the front of the bulworke	*F G*. 280.	2, 44715.
so sine the inward flanking angle	s. *S G F*. 21.d. 26'.	9, 56279.
to the line	*S F*. 102. 31.	2, 00994.

In

In the ſame triangle SGF.

As *Radius* is in proportion
to the front of the bulworke ———— ———— ———— *FG*. 280. — 2,44715.
ſo ſine compl. the inward flanking angle —— s. c. *SGF*. 21. 26. 9,96188.
to the line ———— ———— ———— ———— *SG*. 260. 63. 2,41603.
whereunto adding halfe the curtaine ———— ———— *SI*. 210.
the ſumme is the line ———— ———— ———— — *IG*. 470. 63.
which doubled is the ſide of the
outward heptagon ———— ———— ———— ———— *KG*. 941. 26.

In the triangle IAG.

As ſine halfe the angle at the center ———— s. *IAG*. 25. 43. 0,36259.
to halfe the ſide of the outward heptagon ———— *IG*. 470. 63. 2,67268.
ſo is *Radius* in proportion to the
ſemidiameter of the outward heptagon ———— — *AG*. 1084. 61. 3,03527.

In the ſame triangle IAG.

As ſine halfe the angle at the center ———— s. *IAG*. 25. d. 43'. 0,36259.
to halfe the ſide of the outward heptagon ———— *IG*. 470. 63'. 2,67268.
ſo ſine compl. halfe the angle at the center — s.c. *IAG*. 25 d. 43'. 9,95470.
to the greater perpendiculer ———— ———— *AI*. 977. 17. 2,98997.

In the triangle FCG.

As the ſine of the angle ———— ———— s. *FCG*. 75. d. 43'. 0,01364.
is in proportion to the front ———— ———— *F. G*. 280. —— 2,44715.
ſo ſine halfe the flanked angle ———— s. *FGC*. 42. 51. ½. 9.83261.
to the line ———— ———— ———— ———— *FC*. 196. 52. 2,29340.

In the ſame triangle FCG.

As the ſine of the angle ———— ———— ———— s. *FCG*. 75. d. 43'. 0,01364.
is in proportion to the front - - - - - - - - — *FG*. 280. —— 2, 44715.
ſo is the ſine of the angle - - - - - - - - - - s. *GFC*. 61. d. 26'. 9,94362.
to the head-line - - - - - - - - - - - - - - - - *CG*. 253. 75. 2,40441.
which taken from the greater ſemidiameter ———— *AG*. 1084. 61.
there remaines the ſemid. of the inward heptagon —— *AC*, 830. 86.

In

In the triangle FCN.

As *Radius* is in proportion
to the line before found ———————— *F C.* 196. 52. 2, 29340.
so sine the angle forming the flanke ———— *s. F C N.* 40.d.06. 9,80807.
to the flanke ———————— *F N.* 126. 32. 2,10147.
whereto adding the line first found ———— *S F.* 102. 31.
summe is the distance of the heptagons ———— *I D.* 228.63.
which substracted from the perpend. ———— *A I.* 977.17.
there remaines the perpendicular
of the inward heptagon ———————— *A D.* 748.55.

In the triangle FNC.

As *Radius* is in proportion
to the line before found ———————— *F C.* 196. 52. 2, 29340.
so sine compl. the angle forming the flanke — s.c. *F* C.*N.* 40.d.06. 9,88424.
to the Gorge-line ———————— *N* C. 150. 54. 2,17764.
whereunto adding halfe the curtaine ———— *D N.* 210.
we have the line ———————— *D* C. 360. 54.
which doubled is the side of the inward
pentagon ———————— B C. 721.08.

In the triangle FPN.

As sine the inward flanking angle ———— s.*F* PN. 21. d. 26'. 0,43721.
is in proportion to the flanke ———— *F N.* 126. 32. 2,10147.
so sine compl. the inward flanking angle ——— s.c. *F* P N. 21. 26. 9,96888.
is in proportion to the line ———————— *P N.* 321. 78. 2,50756
which substracted from the curtaine ———— *O N.* 420.00.
remaines the second flanke ———————— *O* P. 98. 22.

Lastly, *in the triangle* ROG.

To the line before found ———————— *S G.* 260.63.
adding the curtaine ———————— *O N.* 420.
the summe is the line ———————— *R G.* 680.63.

 Then

Then First.

As the line *R O* or ——————— ——— *ND*. 228. 63. 7,64087.
is in proportion to that line —— ——————— *RG*. 680.63. 2,83291.
so is *Radius* in proportion
to the tangent of the angle ——————— t. *R O G*. 71. 26′. 10,47378.

Secondly.

As the sine of that angle——————————s: *R O G*. 71: 26. 0 02321.
is in proportion to the line————— ——— *R G*. 680. 63. 2,83291.
so is *Radius* in proportion
to the fixed or longest line of defence——————— *R G*. 718.00. 2,85612.

And after the forme of these examples, you may determine the quantities of the sides, and lines of Forts of any other number of sides, under or above twelve.

5. *Example.*

Lastly, in a Quindecagon of fifteene equall sides and angles, let these parts be as before, namely

The Curtaine———————— *O N*. 42. rods.
The front of the bulworke————— *F G*. 28. rods.
The angle forming the flanke—— — *F C N*. 40.d.06:
And the flanked angle of the bulworke F G H. 90.d. 06.

Then will the other angles be as followeth.

The angle at the center of the poligon —— *B A C*. 24.d.06.
halfe the angle at the center is————— *D A C*. 12. 00.
whose compl. is halfe the angle of the poligon B C A. 78. 00.

which

A Table of the dimensions of any Regular Fortification from the Tetragon to the Dodecagon; the flanked angle being halfe the angle of the Poligon, and 15. degrees.

Poligons the number of their sides	4	5	6	7	8	9	10	11	12
	degrees.	degrees.	degrees.	degrees.	degrees.	degrees.	degrees.	degrees.	degrees.
The angle of the Poligon —— BCE.	90	108	120	$128\frac{4}{7}$	135	140	144	$147\frac{3}{11}$	150
The flanked angle of the bulworke —— FGH.	60	69	75	79 [illegible]/7	$82\frac{1}{2}$	85	87	$88\frac{7}{11}$	90
The angle of the shoulder —— NFG.	105	$109\frac{1}{2}$	$112\frac{1}{2}$	$114\frac{9}{14}$	$116\frac{1}{4}$	$117\frac{1}{2}$	$118\frac{1}{2}$	$119\frac{7}{22}$	120
The inward flanking angle —— SGF.	15	$19\frac{1}{2}$	$22\frac{1}{2}$	$24\frac{9}{14}$	$26\frac{1}{4}$	$27\frac{1}{2}$	$28\frac{1}{2}$	$29\frac{7}{22}$	30
The outward flanking angle —— KMG.	150	141	135	$130\frac{5}{7}$	$127\frac{1}{2}$	125	123	$121\frac{4}{11}$	120
The angle forming the flanke —— FCN.	40	40	40	40	40	40	40	40	40

	rod.	cent	rod.	cent	rod.	cent	rod.	cent	rod.	cent	rod.	cent	rod.	cent	rod.	cent	rod.	cent
The Curtaine —— ON.	42	00	42	00	42	00	42	00	42	00	42	00	42	00	42	00	42	00
The front of the bulworke —— FG.	28	00	28	00	28	00	28	00	28	00	28	00	28	00	28	00	28	00
The Gorge-line —— NC.	10	77	12	18	13	26	14	12	14	83	15	42	15	92	16	36	16	73
The Semidiameter of the inner Poligon —— AC.	44	92	56	45	68	52	80	94	93	63	106	49	119	49	132	57	45	80
The side of the inner Poligon —— BC.	63	53	66	36	68	52	70	24	71	66	72	84	73	85	74	71	75	47
The perpendicular of the inner poligon —— AD.	31	76	45	67	59	34	72	90	86	50	100	06	113	64	127	20	140	83
The Semidiameter of the outer Poligon —— AG.	67	95	80	63	93	74	107	05	120	50	124	02	147	59	161	16	174	83
The side of the outer Poligon —— KG.	96	09	94	79	93	74	92	90	92	22	91	67	91	21	90	83	90	50
The perpendicular of the outter Poligon —— AI.	48	04	65	23	81	18	96	42	111	32	125	93	140	37	154	63	168	87
The distance of the poligons —— DI.	16	28	19	57	21	84	23	52	24	83	25	87	26	72	27	43	28	04
The flanke —— FN.	9	03	10	22	11	13	11	85	12	44	12	94	13	36	13	72	14	04
The head-line —— CG.	23	02	24	18	25	22	26	11	26	87	27	53	28	10	28	59	29	03
The shoulder from the Center —— FC.	14	05	15	90	17	31	18	43	19	36	20	13	20	79	21	35	21	85
The second flanke —— OP.	8	29	13	12	15	13	16	14	16	77	17	14	17	39	17	56	17	68
The longest line of defence —— OG.	70	94	71	14	71	30	71	43	71	55	71	67	71	77	71	86	71	94

A Table of the dimensions of any Regular Fortification from the Tetragon to the Octagon; the flanked angle being ⅔ parts of the angle of the Poligon.

Poligons the number of their sides		4		5		6		7		8	
		degrees.		degrees.		degrees.		degrees.		degrees.	
The angle of the Poligon	BCE.	90		108		120		128 4/7		135	
The flanked angle of the bulworke	FGH.	60		72		80		85 5/7		90	
The angle of the shoulder	NFG.	105		108		100		111 3/7		112 1/2	
The inward flanking angle	SGF.	15		18		20		21 3/7		22 1/2	
The outward flanking angle	KMG.	150		144		140		137 1/7		135	
The angle forming the flanke	FCN.	40		40		40		40		40	
		rod.	cent	rod.	cent	rod.	cent	rod.	cent	rod.	cent
The Curtaine	ON.	42		42		42		42		42	
The front of the bulworke	FG.	28		28		28		28		28	
The Gorge-line	NC.	10	77	12	64	14	00	15	05	15	90
The Semidiameter of the inner Poligon	AC.	44	92	57	23	70	00	83	09	96	43
The side of the inner Poligon	BC.	63	53	67	28	70	00	72	11	73	80
The perpendicular of the inner poligon	AD.	31	76	46	30	60	57	74	86	89	09
The Semidiameter of the outer Poligon	AG.	67	95	81	03	94	62	108	46	122	47
The side of the outer Poligon	KG.	96	09	95	26	94	62	94	13	93	74
The perpendicular of the outter Poligon	AI.	48	04	65	56	81	94	97	72	113	15
The distance of the poligons	DI.	16	28	19	26	21	32	22	86	24	06
The flanke	FN.	9	03	10	60	11	75	12	63	13	34
The head-line	CG.	23	02	23	80	24	62	25	37	26	04
The shoulder from the Center	FC.	14	05	16	50	18	28	19	15	20	76
The second flanke	OP.	8	29	9	36	9	72	9	82	9	79
The longest line of defence	OG.	70	94	71	28	71	56	71	.80	72	00

which doubled is the angle of the poligon- BCE. 156.d.00.
And seeing the flanked ang. of the bulwork FGH. 90.00.
halfe the flanked angle is ——————— FGC. 45.00.
taken from halfe the angle of the poligon — BCA. 78.00.
leaves the inward flanking angle ——————— SGF. 33.00.
whereunto adding a right angle ——————— 90.00.
the summe is the angle of the shoulder —— NFG. 123.00.
from which the c. of the an. forming the flank NFC. 50.00.
rests the angle opposite to the head-line —— GFC. 73.00.
to which adding halfe the flanked angle —— FGC. 45.00.
the summe is ——————————————— 118.00.
which substracted from two right angles ——— 180.00.
remaines the angle opposite to the front ——— FCG. 62.00.
also the c. of the inward flanking angle is —— SFG. 57.00.
which doubled is the outward flanking ang. KMG. 114.00.

Having thus set downe the angles; the sides and other lines are found, as in the foure examples before going, which therefore we passe over, and will next exhibite in two tables, the lines (which we have before shewed to calculate) in a Fort of any number of sides, from the tetragon to the dodecagon, according to the angles found by either of the two rules of the fourth chapter.

In these tables we have set downe the measures of the principall lines in Forts, in rods and centesmes or hundreth parts of rods, accounting (as we have before sayd *Chap.* 1.) 10. foote to a rod, or in rods, feete and tenth parts of feete, thus 70|94 is 70 rods and 94. centesmes of a rod that is $70\frac{94}{100}$ rods or it is 70. rods, 9 foote and 4 tenthes of a foote, and the like is to be understood of the rest.

Many other such tables might be set downe for severall proportions used in fortification, but seeing the Arithmeticall way of calculating them by Logarithmes is so easie, it shall be sufficient to shew some of them, for which purpose we will set downe certaine questions out of *Samuel Marolois* his Fortification, and some others, wherein also you may observe the great facilitie that is in these operations by Logarithmes in comparison of those formerly used by naturall sines, tangents, and secants.

CHAP. VI.

Problemes or Questions, touching such various proportions as are or may be used in Fortification.

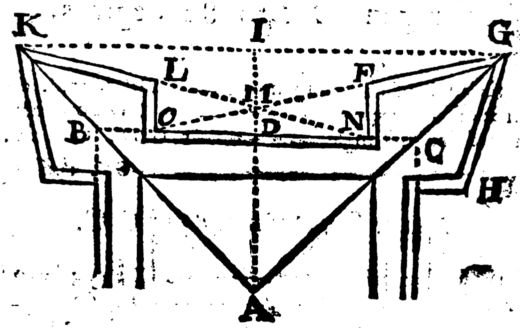
Quest. I.

LEt there be a square, the side thereof B C. containing 35 parts, and let this square be fortified with bulworkes, so as the Gorge-line N C. may be 7 of those parts, the Curtaine

ON.

O N 21. *and the flanke* N F. 5 *parts, and let the front of the bulworke be in a right line with the fixed line of defence, which line of defence suppose to be 60. rods, I demand the quantity of the angles, and of the parts of this Fort?*

Here then in the right angled triangle *O F N.* the curtaine *O N.* being 21. parts, and the flanke *N F.* 5. parts, we may finde the angles, saying



As the flanke ———————— *F N.* 5. parts. 9,30103
is in proportion to Radius
so is the Curtaine ———————— *O N.* 21. parts. 1,3222.

to the tangent of the angle — t. *O F N.* 76. 36. ⅓. 10,6232
whereto is equall the angle ——— *I M G.* 76. 36.
which doubled is the out flanking an. K M G. 153. 13.
also the complement of O F N is — *F O N.* 13. 24.

 also

also the angle ———————— *IG M.* 13. 24.
which taken from halfe the angle
of the tetragon namely from —— *IG A.* 45. 00.
there remaines half the flanked angle. FGC. 31. 36.
which doubled is the flanked angle — *FGH.* 63. 13.
againe to the inward flanking angle — *IG M.* 13. 24.
adding a right angle ———————— 90. 00.
we have the angle of the shoulder — *N F G.* 103. 24.

Now then in the triangle *O G C.* we have the fixed line of defence *O G.* 600. foote, and the angles; for the obtuse angle *O C G.* is the complement of halfe the angle of the tetragon *D C A.* to 180. degrees.

As sine halfe the angle of the tetragon. ——— s. *DCA.* 45.d. 06. 0,1505.
to the fixed line of defence ——————— *O G.* 600. foote. 2,7782.
so sine the inward flanking angle ——— s. *G O C.* 13.d, 24′. 9,3650.
to the head-line ———————————— *G C.* 196. 6. 2,2937.

In the same triangle for O C.

As sine halfe the angle of the tetragon ——— s. *DCA.* 45.d 06. 0,1505.
to the line of defence ——————— *O G* 600. foote. 2,7782.
so sine halfe the flanked angle ——— s. *O G* . 31. 36. 9,7193.
to the curtaine, and Gorge line ——— *O C.* 444.7. 2,6480.
the fourth thereof is the Gorge ——— *N C.* 111. 2.
the residue is the curtaine ——————— *O N.* 333. 5.
Also the summe of *O C* and *N C* is the
side of the inward tetragon - - - - - - - ——— *B C.* 555. 8.
a seventh part whereof is the flanke — - - - - - - *N F.* 79. 4.

In the right angled triangle O F N *for* O F.

As the sine of the angle ——————— s. *O F N.* 76.d. 36′. 0,0120.
is the proportion to the curtaine ——————— *O N.* 333.5. 2,5231.
so is *Radius* to the distance of the shoulder ——— *O F.* 342. 8. 2,5351.
which taken from the line of defence - - - - - - *O G.* 600.
leaves the front of the bulworke ——————— *F G.* 257. 2.

In

In the triangle ADC *for* AC.

Againe halfe the side of the tetragon is ———— *D C*. 277.9.
whereto is equall the perpendicular ———— *A D*. 277.9.

wherefore

As halfe the angle of the tetragon ———— s. *D C A*. 45 d. 06. 0,1505.
is to the perpendicular ———— *A D*. 277.9. 2,4439.
so is R*adius* in proportion to the
semidiameter of the inward tetragon ———— *A C*. 393.0. 2,5944.
whereunto adding the head-line ———— *C G*. 196.6.
we have the semidiameter of the
outward tetragon ———— *A G*. 589.6.

In the triangle IGA.

As *Radius* is in proportion to the
semidiameter of the outward tetragon ———— *A G*. 589.6. 2,7706.
so sine halfe the angle of the tetragon ———— s. *I G A*. 45.06. 9,8495.
to the perpendicular ———— *A I*. 416.9. 2,6201.
from which taking the perpendic. ———— *A D*. 277.9.
rests the distance of the tetragons ———— *I D*. 139.0.
also to *A I* is equall ———— *I G*. 416.9.
which doubled is the side of the
outward tetragon ———— *K G*. 833.8.

Quest. II.

Let the Curtaine be in proportion to the Gorge-line as 3 to 1. and the Gorge-line to the flanke, as 7 to 5. and let the front of the bulworke be in a right line, with the line of defence, which line of defence suppose to be 60 rods, I demand the quantity of the angles and of the parts of the Fort?

This question is in effect the same with the former.

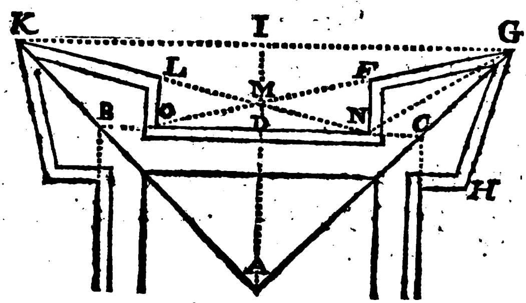
Quest.

Quest. III.

In a quadrangular fortresse, let the Curtaine be foure times so much as the Gorge-line, and let the Gorge-line be equall to the flanke, and let the line of defence be 60. rods, and agree with the front of the bulworke, what shall be the angles and sides of such a Fortresse?

In the triangle FON.

As the Curtaine	*ON*.	4. parts.	9,3979.
is in proportion to *Radius*.			
So is the flanke	*FN*.	1. part.	0,0000.
to tang the inward flanking angle	∟ *FON*.	14 d. 02.	9,3979.
which substracted from halfe the angle of the tetragon	*IGC*.	45.d.06.	
leaves halfe the flanked angle	*FGC*.	30. 58.	
which doubled is the flanked angle	*FGC*.	61. 56.	
Againe the compl. of *FON* or *IGM*. is	*IMG*.	75. 58.	
which doubled is the outward flanking angle	*KMG*.	151. 56.	
Lastly to the inward flanking angle	*FON*.	14.02.	
adding a right angle		90.00.	
we have the angle of the shoulder	*NFG*.	104.02.	



Then

Then for the sides, and first in the triangle OGC.

As sine halfe the angle of the tettagon —— *DCA.* 45. 06. 0,15 05.
to the fixed line of defence —— *OG.* 600. foote. 2,778 2.
To sine the inward flanking angle —— *s. GOC.* 14. 02. 9,3847.
to the head-line —— *CG.* 205. 8. 2,3134.

In the same triangle OGC.

As sine the angle *OCG* or —— *s. DCA.* 45. 06. 0,1505.
to the line of defence —— *OG.* 600. foote. 2,7782.
so sine halfe the flanked angle —— *s. FGC.* 30. 58. 9,7114.
to the curtaine and gorge-line —— *OC.* 436. 6. 2,6401.
the fift part whereof is the gorge-line —— *NC.* 87. 3.
Whereto is equall the flanke —— *NF.* 87. 3.
and substracting *NC* from *OC*
there remaines the curtaine —— *ON.* 349. 2.

In the triangle FON.

As sine compl. the inward flanking angle —— *s. c. FON.* 14.d. 62. 0,0132.
is in proportion to the curtaine —— *ON.* 349. 2. 2,5431.
so is *Radius* is proportion
to the distance of the shoulder —— *OF.* 360. 2,5563.
which substracted from the line of defence —— *OG.* 600.
there remaines the front —— *FG.* 240.
Againe if we adde halfe the curtaine —— *DN.* 174. 6.
to the gorge-line —— *NC.* 87. 3.
the summe is the line —— *DC.* 261. 9.
whereto is equall the perpendicular —— *AD.* 261. 9.
and the side *DC* doubled is the side
of the inward tetragon —— *BC.* 523. 8.

In the triangle ADC.

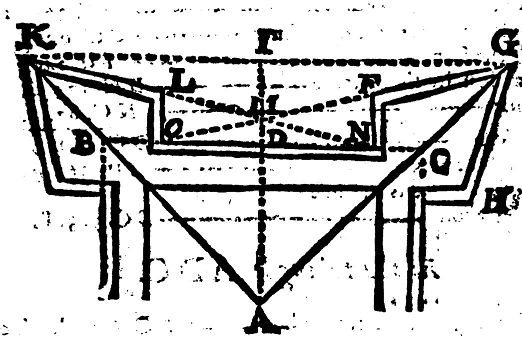
As sine halfe the angle of the tetragon —— *s. DCA.* 45.d. 06. 0,1505.
to the perpendicular —— *AD.* 261. 9. 2,4182.
so is *Radius* in proportion to the
semidiameter of the inward tetragon —— *AC.* 370. 4. 2,5687.
whereunto adding the head-line —— *CG.* 205. 8.
we have the semidiameter of the outward tetragon —— *AG.* 576. 2.

In the triangle I A G.

As Radius is in proportion to the semidiameter of the outward tetragon —— A G. 576. 2. 2,7606
so sine halfe the angle of the tetragon —— I G A. 45. 00. 9,8495.
to the perpendiculer —— A I. 407. 4. 2,6101.
from which substracting —— A D. 261. 9.
remaines the distance of the tetragons —— D I. 145. 5.
Lastly *A I* being here equall to —— I G. 407. 4.
which doubled is the side of the outward tetragon —— K G. 814. 9.

Quest. IIII.

Let there be a Quadrangular Fort whose longest line of defence O G *admit to be 600 foote, the flanked angle* F G H *60 degrees and the angle* F G N *a fourth part of the flanked angle namely 15 degrees, what are the other dimensions of such a Fort?*



Here then halfe the flanked angle —— F G C. 30. 0. 00.
taken from halfe the angle of the tetragon —— I G A. 45. 00.
leaves the inward flanking angle —— I G M. 15. 00.
whereto is equall —— F O N. 15. 00.
the compl. of either is —— I M G. 75. 00.

which

which doubled is the outward flanking angle — K M G. 150. 00.
and if to the angle F O N we adde ———— 90. 00.
we have the angle of the shoulder ———— N F G. 105. 00.
lastly substracting the angle ———— N G C. 15. 00.
from halfe the angle of the tetragon ———— D C A. 45. 00.
there remaines the angle ———— G N C. 30. 00.

In the triangle O G C.

As sine halfe the angle of the tetragon ———— s. D C A. 45. d. 06. 0,1505.
to the fixed line of defence ———— O G. 600. foote. 2,7782.
so is sine the inward flanking angle ———— s G O C. 15. 00. 9,4130.
to the head-line ———— C G. 219. 6. 2,3417.

In the same triangle.

As sine halfe the angle of the tetragon ———— s. D C A. 45. d. 06. 0,1505.
is to the fixed line of defence ———— O G. 600. foote. 2,7782.
so is sine halfe the flanked angle ———— s. O G C. 30. 00. 9,6990.
to the curtaine and one gorge-line ———— O C. 424. 3. 2,6277.

In the triangle G N C.

As the sine of the angle ———— s. G N C. 30. d. 06. 0,3010.
is to the head-line ———— G C. 219. 6. 2,3417.
so is the sine of the angle ———— s. N G C. 15. 06. 9,4130.
to the gorge-line ———— N C. 113. 7. 2,0557.
which substracted from the line ———— O C. 424. 3.
there remaines the curtaine ———— O N. 310. 6.

In the triangle F O N:

As *Radius* is in proportion
to the curtaine ———— O N. 310. 6. 2,4922.
so tang. the inward flanking angle ———— t. F O N. 15. 00. 9,4280.
to the flanke ———— F N. 83. 2. 1,9202.

In the same triangle.

As sine the inward flanking angle — s. F O N. 15. d. 06. 0,5879.
is in proportion to the flanke — F N. 83. 2. 1,9203.
so is *Radius* in proportion
to the distance of the shoulder — O F. 321. 5. 2,5072.
which taken from the line of defence — O G. 600.
leaves the front of the bulworke — F G. 278. 5.

In the triangle A D C.

And if unto halfe the curtaine — D N. 155. 3.
we adde the gorge-line — N C. 113. 7.
the summe is the line — D C. 269. 0.
whereto is equall the perpendicular — A D. 269. 0.
Also the line D C doubled is the side
of the inward tetragon — B C. 538. 0.

As sine halfe the angle of the tetragon — s. D C A. 45. d. 06. 0,1505.
to the perpendiculer — A D. 269. 0. 2,4300.
so is *Radius* in proportion to the
semidiameter of the inward tetragon — A C. 380. 4. 2,5805.
whereunto adding the head-line — C G. 219. 6.
we have the semidiameter of the
outward tetragon — A G. 600. 0.

In the triangle I G A.

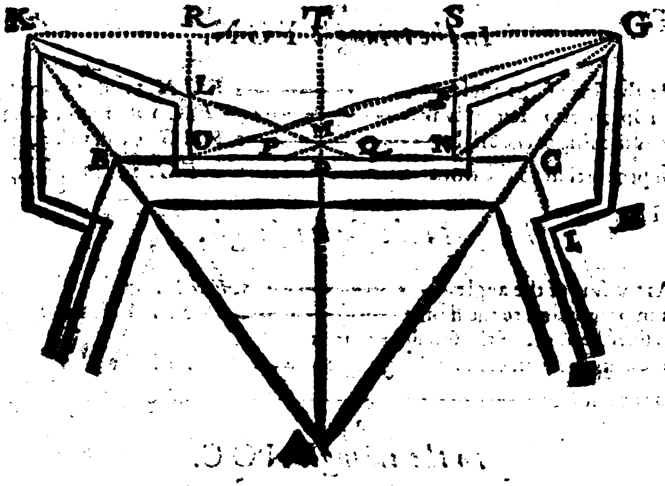
As *Radius* is in proportion to the
semidiameter of the outward tetragon — A G. 600. 2,7781.
so sine halfe the angle of the tetragon — s. I G A. 45. d. 06. 9,8495.
to the perpendiculer — A I. 424. 3. 2,6276.
from which substracting the perpend. — A D. 269. 0.
rests the distance of the tetragons — I D. 15[illegible].
Lastly, I G. (which is equall to A I) doubled is
the side of the outward tetragon — K G. 848. 5.

We set downe the measures of the parts in feete, and tenth parts of feete, that being alwayes or for the most

most part sufficient, but when you desire more exact-nesse, you may use the logarithmes, to the eight places, or unto sixe places as in this next question wee have done.

Quest. V.

In this figure of a Pentagonall Fort, let the flanked angle be 69. degrees, and let the angle F G N *be a fourth part thereof, namely* 17. d. 15'. *and the flanke* F N. 10. *rods and 8 foote; and the Curtaine* O N 36. *rods; I demand the quantity of each part of such a Fort?*



From halfe the angle of the pentagon ——— [illegible] 54.d. 00.
substract halfe the flanked angle ——— F G C. 34. 30.
resteth the inward flanking angle *I G P* or ——— F P N. 19. 30.
which added to a right angle ——— 90.
makes the angle of the shoulder ——— *N F G*. 109. 30.
And if from halfe the angle of the
pentagon we substract the angle ——— *N G C*. 17.d. 15'.
there remaines the angle ——— *G N C*. 36.45.
whose complement is ——— *F* N *G*. 53. 15.

First then in the triangle FPN.

As sine the inward flanking angle ——— s. *F P N*. 19.d. 30'. 0,47650.
is in proportion to the flanke ——— *F N*. 108. foote. 2,03342.
so sine compl. the same angle ——— s. c. *F P N*. 19. 30. 9,97435.
to the part of the curtaine ——— P *N*. 304. 98. 2,48427.
which substracted from the curtaine ——— *O N* 360.
there remaines the second flanke ——— *O P*. 55. 2.

In the triangle FGN.

As the sine of the angle ——— s. *F G N*. 17. d. 15'. 0,52791.
is in proportion to the flanke ——— *F N*. 108. foote. 2,03342.
so is the sine of the angle ——— s. *F N G*. 53.d. 15'. 9,90377.
in proportion to the front ——— *F G*. 291. 81. 2,46510.

In the same triangle.

As the sine of the angle ——— s. *F G N*. 17. d. 15'. 0,52791.
is in proportion to the flanke ——— *F N*. 108. foote. 2,03342.
so sine the angle of the shoulder that is
sine compl. the inward flanking angle ——— s.c. F P *N*. 19. 30. 9,97435.
to the distance ——— *N G*. 343.30. 2,53568.

In the triangle N G C.

As sine halfe the angle of the pentagon ——— s. *D C A*. 54.d.00.0,09204.
to the distance before found ——— *N G*. 343. 30. 2,53568.
so sine ¼ of the flanked angle ——— s. *N G C*. 17. 15. 9,47209.
to the gorge-line ——— *N C*. 125.84. 2,09981.

In the same triangle.

As sine halfe the angle of the pentagon —— s. D C A. 54.d. 06. 0,09204.
is in proportion to the sayd distance —— N G. 343.30. 2,53568.
so the sine of the angle —— s. G N C. 36. 45. 9,77694.
to the head-line —— C G. 253.90. 2,40466.

In the triangle OGN.

As the summe of O N and NG —— 703. 30. 7,15286.
is to the difference of O N and N G —— 16,70. 1,22272.
so tang. halfe the angle G N C —— t. 18.d. 22′. ½. 9,52136.
to the tangent of the difference —— 00. 27 ⅞. 7,89694.
which added makes the angle —— O G N. 18. d. 49. ⅞.

Secondly.

As the sine of that angle —— s. O G N. 18. d. 49′ ½. 0,49118.
is in proportion to the curtaine —— O N. 360. —— 2,55630.
so the sine of the angle —— s. G N C. 36. d. 45′. 9,77694.
to the longest line of defence —— O G. 667.46. 2,82442.

In the triangle A D C.

Halfe the curtaine is —— D N. 180 foote.
and the gorge-line is —— N C. 125. 84.
the summe of these —— D C. 305. 84.
which doubled is the side of the inward pentagon — B C. 611.67.
As tang. halfe the angle at the center —— t. D A C. 36. d. 06. 0,13873.
to halfe the side of the inward pentagon —— D C. 305. 84. 2,48549.
so is Radius in proportion to the
the lesser perpendiculer —— A D. 420.94. 2,62422.

In the same triangle.

As sine halfe the angle at the center —— s. D A C. 36. d. 06. 0,23078.
to halfe the side of the inward pentagon —— D C. 305. 84. 2,48549.
so is Radius in proportion to the
semidiameter of the inward pentagon —— A C. 520.32. 2,71627.
whereto adding the head-line —— C G. 253.90.
we have the semid. of the outward pentag. —— A G. 774.22.

In

In the triangle FGA.

As Radius is in proportion to the
semidiameter of the outward pentagon ———— AG. 774. 22. 2,88886.
so sine halfe the angle at the center ———— s. IAG. 36 d. 06. 9,76922.
to the line ———— IG. 455. 08. 2,65808.
which doubled is the side of the outward
pentagon ———— KG. 910. 16.

In the same triangle.

As Radius is in proportion to the
semidiamet. of the outward pentagon ———— AG. 774. 22. 2,88886.
so sine halfe the angle of the pentagon ———— s. IGA. 54. d. 06. 9,90796.
to the perpendiculer ———— AI. 626. 36. 2,79682.
from which substracting the perpend ———— AD. 420. 94.
there remaines the distance of the pentagons ———— DI. 205. 42.

Quest. VI.

In the hexagonall Fort following; Let the front of the bulwarke be in proportion to the Curtaine as 2 to 3. and to the flanke, as 5 to 2. and let the distance of the diamond points of the bulwarkes KG. *be* 84. *rods, and the flanked angle of the bulwarke,* 75. d. *I would know the fronts, curtaines and other lines of such a Fort?*

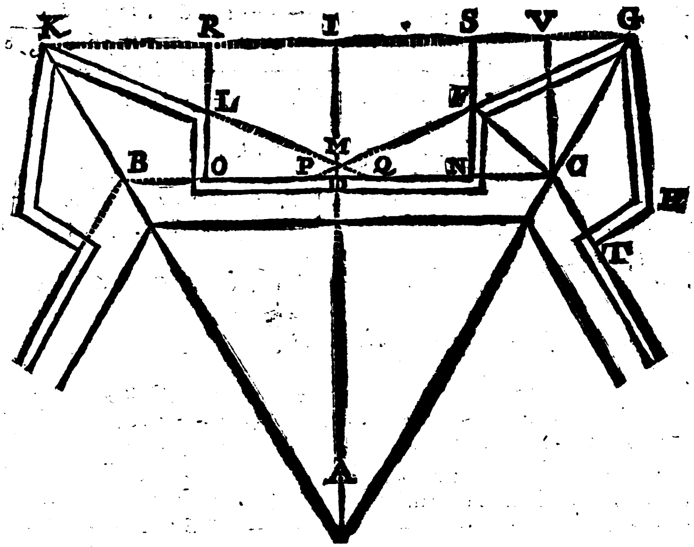
From halfe the angle of the hexagon ———— SGC. 60. d. 06.
take halfe the flanked angle ———— FGC. 37. 30.
reste the inward flanking angle ———— SGF. 22. 30.
whose complement is ———— SFG. 67. 30.

First

First then in the triangle S F G.

As *Radius* is in proportion
to the front of the bulworke——— *F.G.* 2. parts. 0, 3010.
so the sine of the angle——— s. *S F G.* 67. d. 30. 9, 9656.
to the line ——— *S G.* 1.8478. 0,2666.
whereunto adding halfe the curtaine ——— *D N.* 1. 5000.
we have the line——— *I G.* 3. 3478.

Which being halfe the distance of the diamond points of the Bulworkes *K G*, is by supposition *I G.* 42. roddes or 420. feete.



 As

As the line *I G.* in parts ——— *I G.* 3.3478. co. ar. 9,47524.
is to the front *F G.* in parts ——— *F G.* 2 parts. — 0,30103.
so is the same line *I G.* in feete ——— *I G.* 420 feete. — 2,62325.
to the sayd front *F G.* in feete. ——— *F G.* 250.9. — 2,39952.

As the front in parts ——— *F G* 2. 9,6990.
is to the curtaine in parts ——— *O N.* 3. 0,4771.
so is the front in feete ——— *F G.* 250.9. 2,3995.
to the curtaine in feete ——— *O N.* 376.4. 2,5756.

As the front in parts ——— *F G.* 5. 9,3010.
is to the flanke in parts ——— *F N.* 2. 0,3010.
so is the front in feete ——— *F G.* 250.9. 2,3995.
to the flanke in feete ——— *F N.* 100.4. 2,0015.

In the triangle S G F.

As *Radius* is in proportion
to the front of the bulworke ——— *F G.* 250.9 2,3995.
so sine the inward flanking angle ——— s. *S G F.* 22.d. 30 9,5828.
to the line ——— *S F.* 96.0. 1,9823.
whereto adding the flanke ——— *F N.* 100. 4.
we have the distance of the hexagons *N S.* or ——— *C V.* 196.4.

In the triangle V G C.

As sine halfe the angle the hexagons *N S.* or ——— *C V.* 60.d.00.0,0625.
to the distance of the hexagons *N S* or ——— *V C.* 196.4. 2,2931.
so is *Radius* in proportion
to the head-line ——— *C G.* 226.8. 2,3556.

And as

The side of the outward hexagon is ——— *K G* 840.
so is the semidiamer, of the same hexagon ——— *A G.* 840.
from which substracting the head-line ——— *C G.* 226. 8.
rests the semid. of the inward hexagon ——— *A C.* 613. 2.
whereto is equall the side of the
inward hexagon ——— *B C.* 613. 2.
the halfe whereof is ——— *D C.* 306. 6.
from which substracting halfe the curtaine ——— *D N.* 188. 2.
there remaines the Gorge-line ——— *N C.* 118. 4.

In

In the triangle ADC.

As Radius is in proportion to the
semidiameter of the inward hexagon ———————— *AC*. 613. 2. 2,7876.
so sine halfe the angle of the hexagon ———— *s. DCA*. 60. d. 00. 9,9375.
to the perpendicular ———————————— *AD*. 531. 1. 2,7251.
&c. as before.

Quest. VII.

Let there be a hexangular Fort, and let the distance of the diamond points of the bulworkes be 86 rods 4. foote, the Curtaine 38 rods 4 foote, the flanke 10 rods, and the flanked angle of the bulworke 75. d. 06. what shall bee the fronts, the longest and shortest lines of defence, the gorges and other parts of this fort?

Quest. VIII.

In a hexangular fort, let the Gorge-line be in Proportion to the flanke, as 10. *to* 7. *and to the side of the inward hexagon as* 2. *to* 9. *and let the second flanke be in proportion to the first, as* 6. *to* 7. *and the longest line of defence* 72. *rods: what shall be the other parts of such a Fort?*

Quest. IX.

In a fort of 6. *sides, the front being* 29. *rods, and the curtaine in proportion to the front as* 4. *to* 3. *and the angle forming the flanke* 40. d. *I demand the other dimensions of such a fort?*

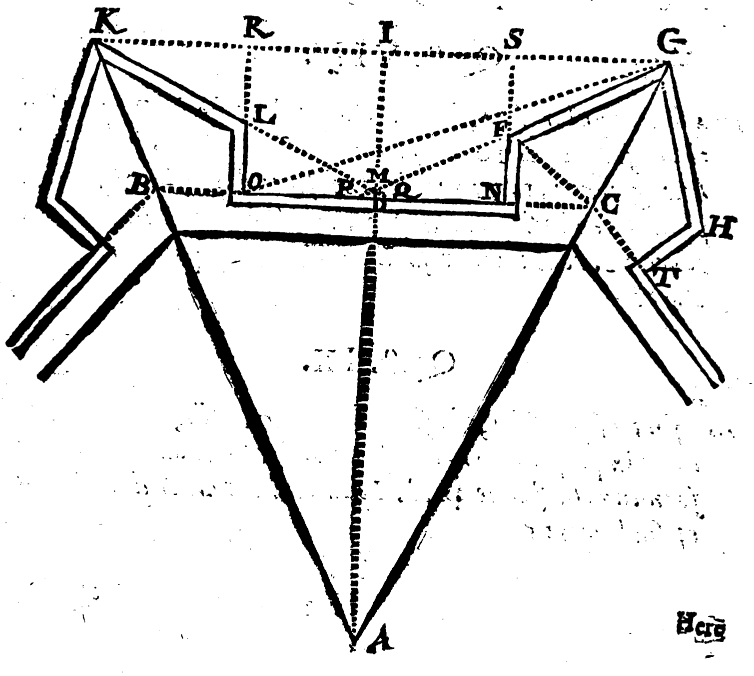
 Quest.

Quest. X.

In a fort of sixe sides, admit the flanked angle of the bulworke to be 80. d. *and the front in proportion to the curtaine as* 2. *to* 3. *and let the front be* 29. *rods, and the angle forming the flanke* 40. *degrees: what are the dimensions of the other parts of such a Fort?*

Quest. XI.

There is a regular fort of 7. *bulworkes whose flanke is* 12. *rods, and the distance of the angular points of its bulworkes is* 86. *rods* 4. *foote, and the flanked angle of the bulworke* 80. d. *I would know the other dimensions of this heptagon supposing the second flanke to be* 12. *rods?*



Here according to the third chapter I finde
the angle at the center of the heptagon——— *B A C*. 51. d. 26. fere,
the halfe thereof ——— *A.D.A.C.* 25.43.
whose complem. is halfe the angle of the heptagon—*D.C.A.*64.17.
from which substracting halfe the flanked angle——— *F G C*. 40,00.
there remaines the inward flanking angle——— *I G P*. 24. 17.
whereto is equall the angle——— *G P C*. 24. 17.
the complement of either is *P F N* or——— *S F G*.65.43.
which doubled is the outward flanking angle——— *K M G*. 131,26.
Also the compl. of *S F G*. to 180. d. is the angle of
the shoulder ——— *N F G*. 114. 17.

Then for the sides, and first in the triangle F P N.

As sine the inward flanking angle——— s. *F P N*.24.d.17′. 0,3858.
is in proportion to the flanke——— *F N*. 120. foote. 2,0792.
so is the sine of the angle——— s. *P F N*.65.d. 43′. 9,9598.
to the intersection of the curtaine——— *P N*. 266. 0. 2,4248.
whereto adding the second flanke——— *O P*.120.
we have the curtaine ——— *O N*. 386. foote. fere.

In the same triangle.

As sine the inward flanking angle——— s. *F P N*. 24. d. 17′. 0,3859.
is in proportion to the flanke——— *F N*. 120. foote. 2,0792.
so is *Radius* in proportion
to the line——— P *F*. 291.8.2,4651.

In the triangle S G F.

From the side of the outward heptagon ——— *K G*. 864.
substracting the curtaine *R S* or ——— *O N*. 386.
there remaines the summe of *K R* and ——— *S G*. 478.
the halfe whereof is the line——— *S G*. 239.

As the sine of the angle——— s. *S F G*.65.d.43′.0,0402.
is in proportion to the line——— *S G*. 239. foote. 2,3784.
so sine the inward flanking angle——— s. *S G F*. 24.17. 9,6141.
to the line——— *S F*. 107. 8. 2,0327.
which added to the flanke——— *N F*. 120.
gives the distance of the heptagons——— *N S*. 227. 8.

In the same triangle.

As the sine of the angle ———————— s. *S F G.* 65. d. 43'. 0,0402.
is in proportion to the line ———————— *S G.* 239. 2,3784.
so is *Radius* in proportion
to the front of the bulworke ———————— *F G.* 262. 2. 2,4186.
whereto adding the line before found ———— *P F.* 291. 8.
we have the shortest line of defence ———— *P G.* 554. 0.

In the triangle G P C.

As sine halfe the angle of the heptagon —— s. *D C A.* 64. d. 17'. 0,0453.
is in proportion to the line ———————— *P G.* 554. 2,7435.
so sine the inward flanking angle ———— s. *G P C.* 24. 17. 9,6141.
to the head-line ———————— *C G.* 252. 9. 2,4030.

In the same triangle.

As sine halfe the angle of the heptagon —— s. *D C A.* 64. d. 17'. 0,0453.
to the shortest line of defence ———————— *P G.* 554. 2,7435.
so is the sine of halfe the flanked angle ——— s. *P G C.* 40 d. 06. 9,8081.
to the line ———————— *P C.* 395. 3. 2,5969.
from which substracting the line ———— *P N.* 266.
there remaines the gorge-line ———————— *N C.* 129. 3.

In the triangle I A G.

As sine halfe the angle at the center ——— s. *I A G.* 25. d. 43'. 0,3626.
to halfe the side of the outward heptagon ———— *I G.* 432. 2,63555.
so is *Radius* in proportion to the
semidiamet. of the outward heptagon ———— *A G.* 995. 6. 2,9981.
from which substracting the head-line ———— *C G.* 252 9.
leaves the semid. of the inward heptagon ———— *A C.* 742. 7.

If further you desire the fixed line of defence *O G.* you have the right angle triangle, *O R G.* the base *R G.* 615. feete, and the perpendiculer *O R.* 227. 8. whereby *O G.* is easily found by the first case of plaine triangles.

Quest.

Quest. XII.

There is a regular Fort of 7. sides, whose flanke is a 11. rods, the distance of the angular points of the bulworkes, 87. rods, the flanked angle of the bulworke 80. d. *I would know the other parts of this fort, supposing the second flanke to be 9. rods?*

Quest. XIII.

There is a heptangular Fort, whose Gorge-line is 14. rods, the flanke 12. rods, and the curtaine 38. rods: I demand the quantity of the other parts of such a septangular fort, the flanked angle of its bulworke being 79 $\frac{2}{7}$. degrees?

Quest. XIIII.

There is a regular Fort of 7. bulworkes the flanked angle of each bulworke being 86. deg. *and the front being 29. rods, is in proportion to the Curtaine as 2. to 3. the angle forming the flanke,* FCN. *admit to be 40. degrees: I would know the dimensions of the other parts of such a Fort?*

Quest. XV.

In a fort of eight angles, let the flanke be 14. rods, the front 29. rods, the curtaine 43. rods, the flanked angle of the bulworke 90. deg. what are the other parts of such a fort?

Quest.

Quest. XVI.

In a fort of eight sides, let the flanke be 13. rods, the second flanke 12. rods, the distance of the angular points of the bulworkes 92. rods, the flanked angle 82. deg. 36. what shall be the curtaines, fronts, gorges, and other parts of such a fort?

Quest. XVII.

Let the flanked angle of the bulworke be 90. deg. the angle forming the flanke FCN. *40. deg. and let the front be in proportion to the curtaine as 2. to 3. supposing then the front to be 24. rods; what shall be the other parts of such a fort of 8. sides.*

Quest. XVIII.

Let there be a fort of 9. bulworkes, whose curtaine let be 39 rods, the front of each bulworke 26, the flanke 13 rods: what shall be the other parts of such a fortresse, supposing the flanked angle of each bulworke to be 85. degrees?

Quest. XIX.

In a fort of 9. sides, let the flanked angle be 85. deg. *the shortest line of defence 60. rods, the longest line of defence 72. rods. I demand the quantities of the other parts of such a fort, supposing the Gorge-line to be in proportion to the flanke as 4. to 3?*

Quest. XX.

There is a fort of nine sides, whose flanked angle is 85. deg. the shortest line of defence scowring the front 60. rods, and the longest line of defence drawne from the flanke 72. rods, the perpendicular from the angular point of the bulworke to the flanke extended SG. *is equall to the distance of the outward and inward Nonagons* SN. *and either of them in proportion to the side of the outward nonagon, as 2 to 7. what shall be the other parts of such a fort?*

Quest. XXI.

Admit that of a regular fort having ten sides, the flanked angle be 87. deg. *the Gorge-line in proportion to the flanke, as 4. to 3. and the lines of defence, namely the shortest 60. rods, and the longest 72. rods: what will be the other parts of such a fort?*

Quest. XXII.

Againe admit in such a fort the flanked angle be 87. deg. *the fixed line of defence 72. rods, the flanke 13 ½. rods, and the gorge-line 18. rods; there is required the other parts of such a fort?*

Quest. XXIII.

In a fort of a eleven sides, let the front be in proportion to the curtaine, as 2. to 3. and the gorge-line to the flanke, as 4 to 3. and let the distance of the angular points of the bulworkes be 90. rods, and the flanked angle of the *bulworke* 88 $\frac{7}{11}$ deg. *I would know the other parts of such a fort?*

Quest. XXIIII.

In such a Fort, let the front be in proportion to the curtaine as 2 *to* 3. *and the gorge-line to the flanke, as* 8. *to* 5. *and let the fixed line of defence be* 72. *rods: what shall be the other parts of such a Fort, the angle of the bulworke being* 88 $\frac{7}{11}$ *degrees?*

Quest. XXV.

In a fort of 12. *sides let the flanke be* 14. *rodds, the front* 28. *rods, and the curtaine* 42. *rods, and the flanked angle of the bulworke* 90. deg. *and let the other parts of such a fort be required?*

Quest. XXVI.

In a fort of 12. *sides, let the shortest line of defence scowring the front be* 54. *rods and the longest line of defence* 72. *rods, and let the gorge-line be in proportion to the flanke, as* 4. *to* 3. *and the flanked angle of the bulworke* 90. deg. *what shall be the other parts of such a fort?*

Quest. XXVII.

In such a fort let the flanked angle be a right angle, and the angle forming the flanke 38. deg. *the front of the bulworke* 28. *rods, and the longest line of defence,* 72. *rods; what shall be the dimensions of the other parts of such a fort?*

Sundry other ſuch queſtions or problemes are and may be framed, according to the ſeverall proportions uſed by ſeverall nations and by ſundry men.

As *Speckelius* aſſuming the ſide of the inward poligon to be 100. rods, would have the Curtaine to be 50. and the front 40. and the flanke 15. rods.

The *Italians* (according to the ſame *Speckelius*) make the ſide of the poligon to be fortified 80. rods.

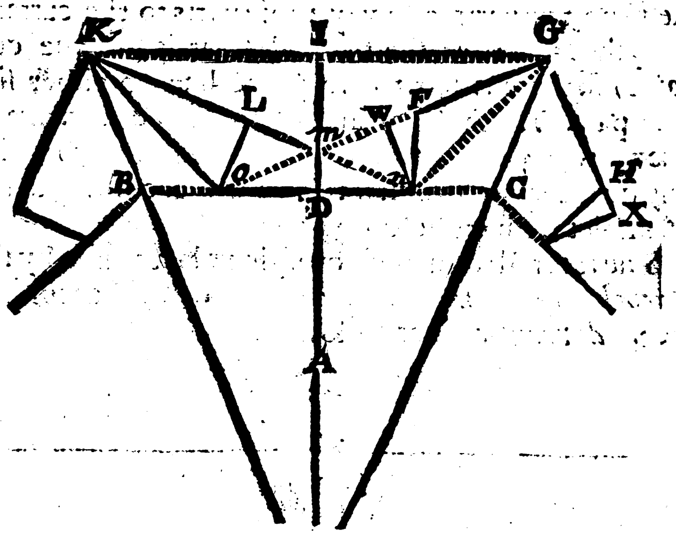
Some in the largeſt Fort would have the front 40. rods in a meane fort 35. and in the leaſt 30. rodds. And the curtaine in proportion to the front, as 5 to 4. and the flanke in proportion to the front as 2 to 5.

Others dividing the ſide of the poligon to be fortified into five parts, allow of thoſe parts to the curtaine 3. to the front 2. to the flanke $\frac{3}{4}$ (that is $\frac{1}{4}$ of the curtaine) ſo there is left to the gorge-line on either ſide one part. To theſe or any of theſe the doctrine of triangles may be aptly applyed, and will eaſily reſolve any queſtions or Problemes incident according to the examples we have before given.

The ſeverall formes of fortifying places, uſed by the *French*, *Spaniards*, *Hollanders*, and *Italians*, according to Sr. *de Praiſſac* are as followeth.

THE FRENCH FORTIFICATION.

AS in this figure, let *A G.* and *A K.* be the semidiameters of the outward poligon, and *K G.* the side thereof which is also the distance of the anguler points of the bulworks, then making the angle *O G A.* and *N K A* (or which are the same *O G C.* and *N K B.*) either of them 45. deg. the whole flanked angle of the bulworke



F G H will be 90. deg. that is a right angle: And againe subdividing the angles, *F G C.* and *L K B.* into two equall parts by the line *G N* and *K O* draw by the intersections

sections, at *O.* and *N.* the curtaine *O N.* and so *O G.* and *N K.* are the lines of defence, To which lines of defence, letting fall from the points *O.* and *N.* the perpendiculars *O L.* and *N W.* they are the flankes; and *L K.* and *W G.* the fronts of the bulworkes, in such forts as have not more than eight sides; but in forts that have more than eight sides, the flankes are perpendiculer to the curtaines, as *N F.* and then the front is *F G.*

Here then according to this designe, knowing the number of the sides of the poligon, we may finde all the angles, according to the method and example following, as suppose this to be an Octagon.

From halfe the angle of the poligon ——	I G C.67.d.30.
substracting halfe the flanked angle ——	M G C.45.
there rests the inward flanking angle ——	I G M.22. 30.
whose complement is the angle ——	I M G.67.30.
which doubled is the outward flanking an.	K M G.135.00.
also substracting the angle 22.d.30. ——	N G C.22.30.
from halfe the angle of the poligon ——	D C A.67.30.
there remaines the angle ——	G N C.45.00.
whose complement is the angle ——	F N G.45.00.
also the compl. of W G N.22.d.30. *is* —	W N G.67.30.
and the comp. of N O W.22.d.30. *is* —	W N O.67.30.

Now if there be further the quantity of some one of the sides or lines determined, we may finde the rest.

As if there were given the curtaine *O N.* wee may in the right angled triangle *N O W.* finde the flanke *N W.* and in the right angled triangle *N W G.* the front *W G.* &c.

 So

So if there were given the front, *W G.* wee might thence find the flank *W N.* and thence the curtaine *O N.* then the line of defence *O G*; and so the rest.

As suppose in this fort of 8. sides we determine the line of defence to be 72. roddes or 720. foote.

Then first in the triangle O G N.

As the sine of the angle *O N G.* or ——— s. *G N C.* 45.06. 0,1505.
to the line of defence ——— *O G.* 720. foote. 2,8574.
so sine a fourth of the flanked angle ——— s. *O G N.* 22.d.30. 9,5828.
to the curtaine ——— *O N.* 389.7. 2,5907.

In the triangle O G C.

As sine halfe the angle of the poligon ——— s. *D C A.* 67. d. 30. 0,0344.
to the line of defence ——— *O G.* 720. 2,8573.
so sine halfe the flanked angle ——— s. *O G C.* 45. 06. 9,8495.
to the line ——— *O C.* 551. 1. 2,7412.
from which substracting the curtaine ——— *O N.* 389. 7.
there remaines the Gorge-line ——— *N C.* 161. 4.
which added to halfe the curtaine ——— *D N.* 194. 8.
the summe is the line ——— *D C.* 356. 2.
which doubled is the side of the inward poligon ——— *B C.* 712. 4.

In the same triangle.

As sine halfe the angle of the poligon ——— s. *D C A.* 67. d. 36. 0,0344.
to the line of defence ——— *O G.* 720. 2,8573.
so sine the inward flanking angle ——— s. *G O C.* 22. 30. 9,5828.
to the Head-line ——— *C G.* 298. 2. 2,4745.

In the triangle N O W.

As *Radius* is in proportion
to the curtaine ——— *O N.* 389.7. 2,5907.
so sine the inward flanking angle ——— s. *N O W.* 22. 30. 9,5828.
to the flanke ——— *N W.* 149. 1. 2,1735.

In

In the same triangle.

As *Radius* is in proportion
to the Curtaine ——————— O N. 189.212,5907.
so sine compl. the inward flanking angle ——— s.c. NON. 22.30.9,9656.
to the distance of the shoulder ——————— O W. 360.0.2,5563.
which taken from the line of defence ——————— O G. 720.0.
leaves the front of the bulworke ——————— W G. 360.0.

The front is here one halfe of the line of defence, because the triangles *O N W.* and *G N W.* are equall and Equiangle.

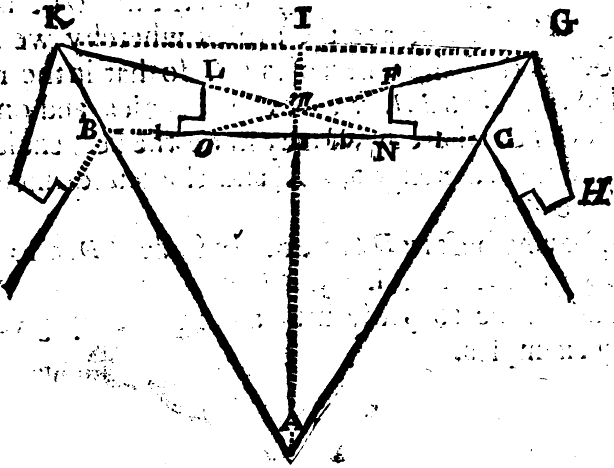
If further you desire the side of the outward poligon *K G.* we have in the triangle *K O G.* the side *O G.* being the line of defence, and the angles whereby we may finde *K G.* the halfe whereof is *I G.* so that in the right angled triangle *G I A.* we have the angles and one of the sides *I G.* whereby we may finde the perpendicular of the outward poligon, *A I.* and the semidiameter of the same *A G.*

Or having before *D C.* we might finde *A D.* also *A C.* and so *A G.* then *I G.* lastly *A I.* and so *I D.* which we shall not neede to prosecute, having already given so many examples.

THE

THE SPANISH FORTIFICATION with Casemates.

DIvide the side of the inward poligon *B C.* into 8. equall parts, and let the Gorge-lines *O B.* and *N C.* be either of them two of those parts, and the flankes *O L.* and *N F.* either of them one of those parts, and perpendicular to the curtaines; and let the lines of



defence *O G.* and *N K.* be drawne from the angles of the flankes *O.* and *N.* by the shoulders *F.* and *L.* till they concurre with the head lines at the points *G* and *K.*

If then the quantity of some one of these lines be determitermined, we may finde the other sides and angles of such a fort.

As in this fort of sixe sides, let the line of defence *O G*. be 85. rods, and the other sides and angles required; then forasmuch as the curtaine *O N*. is foure such parts as the flanke *N F*. is one therefore in the right angled triangle *O F N*. I say,

As the curtaine ———————— *O N*. 4. parts. 9, 3979.
is in proportion to *Radius*
so is the flanke ———————— *N F*. 1. part. 0, 0000.
to tang. the angle ———————— t. *F O N*. 14. d. 62. 9, 3979.
equall to the inward flanking angle ———— *I G M*. 14. 2.
whose complement is the angle ———— *I M G*. 75. 58.
which doubled is the outward flanking angle —— *K M G*. 151. 56.
againe the inward flanking angle ———— *I G M*. 14. 02.
taken from halfe the angle of the poligon —— *I G A*. 60. 00.
leaves halfe the flanked angle ———— *F G C*. 45. 58.
which doubled is the flanked angle ———— *F G H*. 91. 56.

In the triangle G O C.

As sine halfe the angle of the poligon —— s. *D C A*. 60. d. 06. 0, 0625.
to the line of defence ———— *O G*. 850. foote. 2, 9294.
so sine the inward flanking angle ———— s. *G O C*. 14. d. 62. 9, 3847.
to the head-line ———————— *C G*. 238. foote. 2, 3766.

In the same triangle.

As sine halfe the angle of the poligon ———— s. *DCA*. 60. d. 06. 0, 0625.
is to the line of defence ———————— *O G* 850. foote. 2, 9294.
so sine halfe the flanked angle ———————— s. *O G C*. 45. 58. 9, 8567.
to the line ———————————— *O C*. 705. 6. 2, 8486.
A third part whereof is the gorge-line ———— *N C*. 235. 2.
which substracted, remaines the curtaine ———— *O N*. 470. 4.
halfe the gorge-line is the flanke ———— *N F*. 117, 6.

In the triangle O F N.

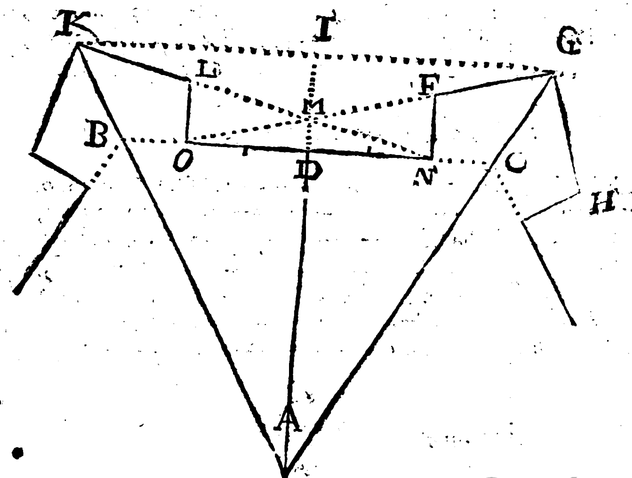
As the sine of the angle *I M G* or ——— s. *O F N.* 75. d. 58′. 0,0132.
is in proportion to the curtaine ——— *ON.* 470.4. 2,6724.
so is sine 90. d. or *Radius*
to the distance of the shoulder ——— *O F.* 484.9. 2,6856.
which substracted from the line of defence ——— *O G.* 850.
there remaines the front ——— *F G.* 365.1.

Thus we might proceede to finde, *A D. A C. A G. I G. A I.* &c. but in this example being for an hexagon, *A C.* is equall to *B C.* and *A G.* to *K G.*

Without Casemates.

Divide the side of the inward poligon *B C.* into 6. equall parts, and let the gorge-lines *N C.* and *B O.* and likewise the flankes *N F.* and *O L.* be every of them one of those parts, and the flankes perpendicular to the curtaine.

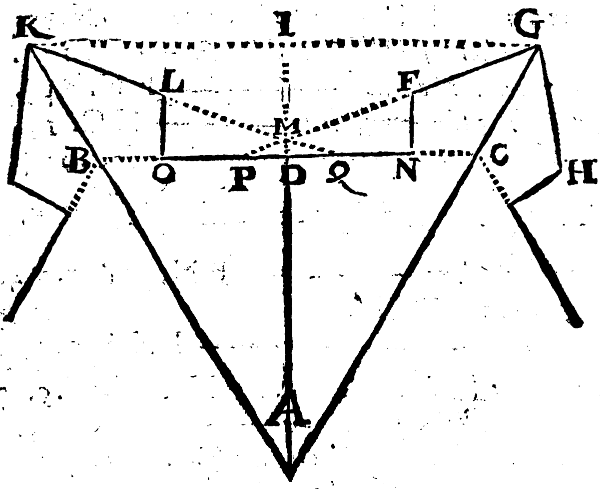
If then the quantity of some one of these lines bee determined in rods or feete, we may finde the quantity of all the other sides and angles, in such a sort, as in the former example.



THE VENETIAN FORTIFICATION.

MAke the Gorge-lines *N C*, and *O B*. and alſo thē flankes *N F*. and *O L*. ēvery of them a ſixth part of the ſidē of the inner poligon. *B C*. that is a ſixt part of the diſtance of the centers of the bulworkes.

And further make the ſecond flankes *O P*. and *Q N*. to be either of them a third part of the curtaine O *N*.



In ſuch forts as havē not abovē ſeven ſides, but in thoſe that have more than ſeven ſides you may makē the ſecond flankes to be either of them one halfe of thē curtaine.

The side of the inner poligon *B C.* exceedes not 100. rods, nor is lesse than 75. rods.

If therefore the measure of any of these parts be given in rods or feete, we may finde the quantity of the other sides and angles.

As admit the side of the inner poligon *B C.* to be 78. rods, and let there be required the other sides and angles: *Then seeing*

The side of the inward poligon is ——— B C. 78. rods.
a sixt part thereof is the gorge-line ——— N C. 13.
to which is equall the flanke ——— N F. 13.
the sum of them both doubled is the gorgeline — 26.
which taken from B C. *leaves the curtaine* ON. 52.
a third part whereof is the second flanke — O P. 17 1/3.
which doubled is the line ——— P N. 34 2/3.
whereto adding the gorge-line ——— N C. 13.
we have the line ——— P C. 47 2/3.

Thus then in the right angle triangle. *P N F.*

As the foresayd line ——— P N. 346. 7. 7,46018.
is in proportion to Radius
so is the flanke ——— F N. 130. 2,1139.
to the tangent of the angle — t. F P N. 20. d. 33′. 9. 5740.
whereto is equall the angle ——— I G M. 20. 33.
which substracted from halfe the angle of the poligon
(*which here suppose to be a hexagon*) I G A. 60. d. 06.
there remaines halfe the flanked angle F G C. 39. 27.
which doubled is the flanked angle — F G H. 78. 54.
also to the angle before found ——— F P N. 20. d. 33.
adding a right angle or ——— 90. d. 06.
we have the angle of the shoulder — N F G. 110. 33.

In

In the same triangle PNF.

As the sine of the angle ———————— s. *F P N*. 20.d. 33'. 0,4547.
is in proportion to the flanke ———————— *F N*. 130. foote. 2,1139.
so is *Radius*
to the line - - - - - - - - ———————— P F. 370.3. 2,5686.

In the triangle PGC:

As the sine of halfe the flanked angle ———— s. *P G C*. 39. d. 27'. 0,1969.
is in proportion to the line ———————— *P C*. 470. 7. 2,6727.
so sine halfe the angle of the poligon ———— s. *D C A*. 60. d. 06. 9,9375.
to the shortest line of defence ———————— *P G*. 641. 4. 2,8071.
from which substracting the line ———— - - - - - *P F*. 370. 3.
there remaines the front ———————— *F G*. 271. 1.

And thus we might proceede to finde the perpendiculars AD. *and* AI. *and so the distance of the poligons* ID. *which cannot be obscure to him that understands the former examples, therefore we passe over this.*

The Fortification used by the *Holanders*, we have before handled more largely.

CHAP. VII.

Of drawing the platforme of a Fort, and marking out the same on the ground, and of fitting an instrument for that purpose.

I Intend not here to handle all parts of the Art of Fortification at large, that being done by others: but rather to shew therein the application or use of this new invention of logarithmes in unfolding the principall mysteries of this Art with much more ease and expedition then by any way of like certainety formerly used: Yet because there is very little written of this subject in our language; and that the things we shall after speake of may be the better understood, I will give an example how to delineate the ground worke of a Fort first on paper, and then how to stake or marke out the same on the ground where such a Fort is intended, and lastly wee shall speake of the workes that are to be raised on such a groundworke, and first for the plat.

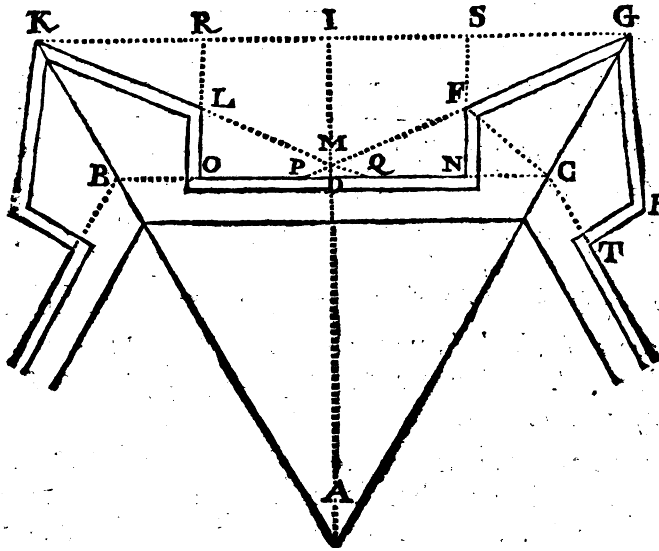
As admit it be required to draw the platforme of a regular Fort of sixe sides or bulworkes, according to some proportion assigned: First then you may finde as hath before beene shewed, the angles sides and other lines in such a Fort requisite to be knowne, which admit to be as followeth, in rods, feete, and tenth parts of feete.

	ro.	f.	ten.
The semidiameter of the outer hexagon	93	7	4
The side of the outer hexagon	93	7	4
The head-line	25	2	2
The semidiameter of the inner hexagon	68	5	2
The side of the inner hexagon as much	68	5	2
The distance of the hexagons	21	8	4
The Gorge-line	13	2	6
The flanke	11	1	3
The second flanke	15	1	3
The fixing or longest line of defence	71	3	0
The Curtaine	42	0	0
The distance from the Center of the bulworke to the shoulder	17	3	1
The front of the bulworke	28	0	0

The angle of the bulworke admit to be 75. deg. *and the other angles answerable, then may we lay these downe many severall wayes.*

Take betweene the feete of your compasse upon a diagonall scale, or other scale of equall parts, the semidiameter of the outer hexagon 93.74. that is, 93. rods, 7. foote, and 4. tenthes of a foote, or 93. rods and 74. centesmes of a rod, and supposing *A*. to be the center of the Fort, upon the point *A*. and distance *AG*. describe a circle, and because the side of a hexagon is equall to the semidiameter, set in the circumference the same measure 93.74. from *G*. to *K*. and so *G*. is the diamond point of one bulworke, and *K*. of another, and draw the lines *A G*. and *A K*. Then taking the semidiameter of the inner hexagon. 68.52. set the same from *A*. to *B*. and *C*. so *B*. and *C*. are the centers of two bulworkes,

workes, and drawing the line *B C.* set downe the gorge-line, 13. 26. from *B.* to *O.* and from *C.* to *N.* the residue of which line namely *O N.* is the curtaine, to which on those parts O. and *N.* raise the perpendiculars, *N. F.* and O. *L.* for the flankes, which flankes may be set off



according to the foresayd measure of 11. 13. or otherwise set off in the curtaine from O. to *P.* and from *N.* to *Q.* 15. 13. for the second flankes, and drawing the shortest line of defence *P G. Q K.* they intersect the perpendiculars raised for the first flankes in the points *L.* and *F.* and so is *N. F.* the flanke, *F. G.* the Front, and in like sort we may proceede, with the other sides of this Fort.

Otherwise having drawne the line *K G.* set downe in the

the ſame the ſide of the outer hexagon, 93. 74. from *K* to *G*. as before, which is the diſtance of the angular points or heads of the bulworkes, then to the right line *K G*. and to the points in the ſame *K*. and *G*. deſcribe the angles *B K G*. and *C G K*. here in the preſent example, each of 60. deg. and in the lines *K B*. and *G C*. ſet off from *K*. and *G*. 25. 22. for the head-lines, which ending at *B*. and *C*. thoſe points *B*. and *C*. are the centers of the bulworkes, wherefore drawing the line *B C*. proceede as before.

Otherwiſe let *K*. and *G*. be the angular points of two of the bulworkes, draw the line *K G*. and on the points *K*. and *G*. deſcribe the angles *A K G*. and *A G K*. (each in this example 60. deg.) and ſet off from *K*. to *B*. and from *G*. to *C*. the head-lines *K B*. and *G C*. drawing as before the line *B C*. then to the line *B C*. and to the point in the ſame *C*. deſcribe the angle *F C N*. of 40. deg. alſo to the line *G A*. and to the point in the ſame *G*. deſcribe halfe the flanked angle *F G C*. which is here 37. deg. 30. and at the concourſe of theſe lines, *C F*. and *G F*. namely at *F*. is the ſhoulder of the bulworke, from which letting fall to the curtaine the perpendicular *F N*. that line *F N*. is the flanke, *N C*. the Gorge-line, *N O*. the curtaine, *F G*. the front, &c. and ſo are the more eſſentiall parts of this Fort deſcribed. Sundry other wayes might be ſhewed, which being of themſelves very eaſie, we over paſſe; neither ſpeake we of the ſcale, which may be the plaine ſcale or ſector, nor of taking the degrees, or parts on that ſcale, ſuppoſing you are already ſo farre initiated in Geometricall practiſes.

Of marking it out on the ground.

In like sort, when you would marke out any such Fort on the ground, you may place your instrument there where you intend the center of your Fort, as at *A.* and from thence set out all the angles at the center, according to the number of the sides of that Fort, which in this example being *6*: those angles also are *6.* and every of them *60.* degrees, which angles set forth by the right lines, *A K. A G*, &c. and in every of those right lines measure by a chaine, divided and subdivided into rods and feete, &c. the semidiameters of the outward and inward poligons, which here are *A C. 68. 5. 2.* that is *68.* rods, *5.* foote, and *2.* tenthes of a foote, and *A G. 93. 7. 4.* setting stakes at the end of those measures, and these are the distances of the centers, and heads or angular points of every bulworke, from the center of the Fort, and being all staked out, if you will examine your worke, you may measure round about from stake to stake, the sides of the outer and inner poligons, or of the outer poligon onely, for the line on the ground from the stake at *K.* to the stake at *G.* is the side of the outer poligon, and the line from the stake at *B.* to that at *C.* is the side of the inner poligon. You may therefore place your instrument at the stake *C.* and thereby draw a line on the ground *F C.* making the angle forming the flanke namely the angle, *F C B. 40.* deg. and the line *F C.* (in this example) *17. 3. 1.* and there set a stake at *F.* for one shoulder of the bulworke. Or otherwise from the stake *C.* towards the stake at *B.* measure the Gorge-line *C N.* (here *13. 2. 6.*) and set a stake at *N.*

for

for the end of the curtaine, from which measuring forwards, towards *B*. 15. 1. 3. that is 15. rods, 1. foote, 3. tenths of a foote, further to Q. there drive a stake, terminating the second flanke, and doe the like from the stake at *B*. towards *C*. then from the stake at the angular point of the bulworke *G*. measure towards the stake at *P*. 28. rods, and there drive a stake at *F*. from which the flanke falls perpendicularly to *N*. and in like sort you may set out the other halfe of the bulworke, *K L O B*. and so is there one side of the Fort staked out, the other sides are all to be set out after the same manner.

The same another way.

Otherwise let *K*. and *G*. represent two stakes on the ground, where you intend shall be the heads or angular points of two bulworkes, then placing your instrument at *G*. by helpe thereof you may line out on the ground, half the angle of the poligon *K G A*. which in this example of an hexagon, is 60. deg. also halfe the angle of the bulworke, *F G C*. which here is 37. deg. 30. and in the line *G A*. measure the head-line *G C*. setting a stake at *C*. for the center of the bulworke, the like you may doe from *K*. driving a stake at *B*. the center of that bulworke. Then placing your instrument at *C*. strike a line on the ground *F C*. making with the line *B C*. an angle of 40. d. and where it concurres with the line *G F*. namely at *F*. there drive a stake for that shoulder of the bulworke, and from *F*. let fall by your instrument a line on the ground *F N*. perpendicular to the line *B C*. and the like you may doe from *B*. and *L*. And thus the lines betweene the stakes *G F.* and *K L.* doe limit the fronts, the lines from the stakes *F N.* and *L O.* the flankes, the lines betweene the stakes *N C.* and *B O.* the Gorge lines, and from *O.* to *N.* the curtaine, and in like sort you may proceede, with all the other sides of this hexagon, and so of any other figure.

Sundry other wayes for lyning out a Fort, might be prescribed, which he that is exercised in Geometricall mensurations, will of himselfe easily conceive.

But before you begin to breake ground, examine all the parts which you have thus staked out, by the other measures set downe in the tables of the fifth chapter, or by the parts calculated, as we have before shewed, and consider all diligently a weeke or more, if time will permit, that so if any thing may be amended, it may bee done before you proceed any further.

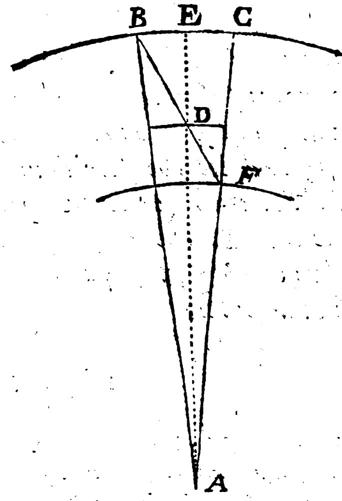
The Instrument fittest for lyning out a Fort is the *Theodelite*, or some other instrument of that nature, the limbe thereof being divided into degrees, and every degree subdivided into *6. 10. 12. 20. 30.* or *60.* parts, that so you may readily count the minutes. The diameter of your Theodelite may be two foote or more, especially if it be of wood, but they are commonly made much lesse, and the degrees in them, as also in semicircles, quadrants, and the like, subdivided by diagonals, the intermediate circles of those diagonalls, being equally distant one from another, which is erronious, especially if the instrument be small, the spaces great, and the diagonall broad: and because this errour is very common, and not touched by any so farre as I know, it will not bee altogether impertinent in this

place

place to shew how by plaine triangles it may be reformed.

To subdivide the degrees, or other parts of the Theodelite, semicircle, quadrant, or other circumference, by a diagonall scale.

Let *A B*. be the semidiameter of the outermost circle *A F*. the semidiamiter of the innermost, and I would divide the arch *B C*. or the angle *B A C*. into two equall parts, by the diagonall *B F*. there is required the semidiameter of the intermediate circle, cutting the diagonall *B F*. so as the parts of it may subtend equall angles at *A*. divide the arch *B C*. into two equall parts in the point *E*. and draw the right line *A E*. which intersects the diagonall *B F*. in the point *D*. then doe the parts of the diagonall line *B D*. and *D F*. subtend equall angles, namely *B A D*. and *D A F*. if therefore on the center *A*. and distance *A D*. there be a circle described it will cut the diagonall *B F*. as is required.



But to finde this distance or semidiameter *A D*. by the Doctrine of triangles, first having determined the greatest

greateſt and leaſt ſemidiameters *A B.* and *A F.* and their contained angle *B A F.* we may finde by the tenth caſe of plaine triangles the angle *A B F.* which being known we have in the triangle *A B D.* the ſide *A B.* and the angles *A B D.* and *D A B.* wherefore by the eighth caſe we may finde the ſide *A D.* and ſo you may proceede by the ſayd eighth caſe to finde the ſemidiameters of any other intermediate circles for dividing the angle *B A F.* into as many equall parts as you will.

Example.

Let the ſemidiameter of the outermoſt circle AB. *be ſixe inches (of which ſize they are often made in braſſe) and ſuppoſing every inch to containe* 1000. *parts this is* 6000. *parts; and let the ſemidiameter of the innermoſt circle* AF. *be* 4. *inches or* 4000. *parts, and the arch* B C. *or the angle* B A C. *one degree, which we would divide into twelve equall parts, by a diagonall, ſo that every part may be five minutes.*

I ſay then

As the ſumme of the ſemidiameters	*AB.* + *AF.* 10000.	6, 00000.
is in proportion to their difference	*A B.* – *A F.* 2000.	3, 30103.
ſo the tang. of the halfe ſumme	t. $\frac{1}{2}$. *F.* + *B.* 89.d.36.	12, 05914.
to the tangent of an angle	t. 87. 36.6'6.	11, 36017.
which ſubſtracted there remaines	*A B F.* 1 d. 59'. 54".	

And ſeeing the angle B A C. *is* 1. deg. *or* 60. *minutes and it is required to divide it into twelve parts, every part will be* 5. *minutes, wherefore ſuppoſing the angle* B A D. *to repreſent that angle of* 5. *minutes, and* A B D. 1. deg.

59.

59. minutes 54″. the sum of them is —— 2. d. 04. 54″. *the complement of the angle* B D A. *to* 180. deg. *which so encreaseth for every twelfth part* 5. *minutes.*

I say then

As the sine of the angle —— *s. B D E.* 2. d. 04. 54″. 1,43980.
to the greatest semidiameter —— *A B.* 6000. parts. 3,77815.
so the sine of the angle at *B.* —— *s. B.* 1. d. 59. 54″. 8,54246.
to the first and lesser semidiameter —— 5760. 3,76041.

And thus we might proceede to finde all the other semidiameters, by adding to the complements arithmeticall of the sines of the severall angles at *D.* the summe of the second and third namely 12, 32061. so shall you have the logarithmes of these numbers following, being the semidiameters of the intermediate circles.

Angle A. in, m.	*Semidia. in parts.*
0	6000
5	5760
10	5538
15	5333
20	5143
25	4965
30	4799
35	4644
40	4499
45	4363
50	4234
55	4113
60	4000

But in this example, and much more in others where a degree or lesse is subdivided into smaller parts, the angles of the triangles being very small, we neede not use the sines of the angles, but the angles themselves reduced into minutes or seconds, for in these the sines of severall angles, and the angles themselves have the same proportion, without sensible difference: that is,

As the sine of —— 1. d. 00.
to the sine of —— 0. d. 30.
so is —— 60.
to —— 30.

And

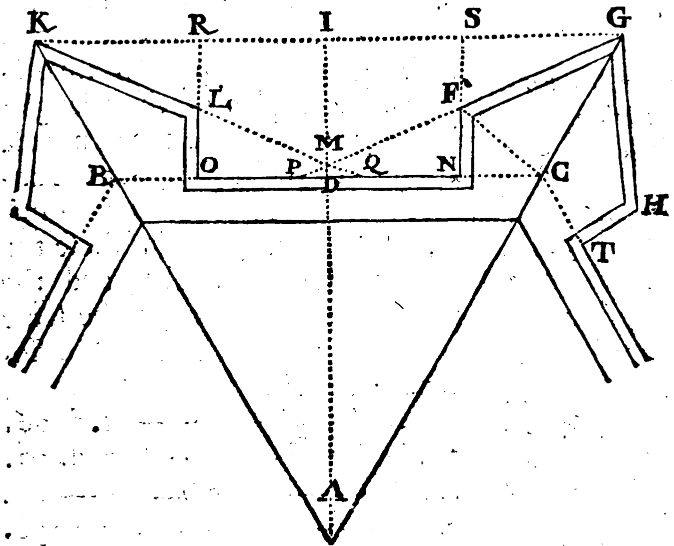
And so of others; But this by the way, now we returne from whence we have digressed.

CHAP. VIII.

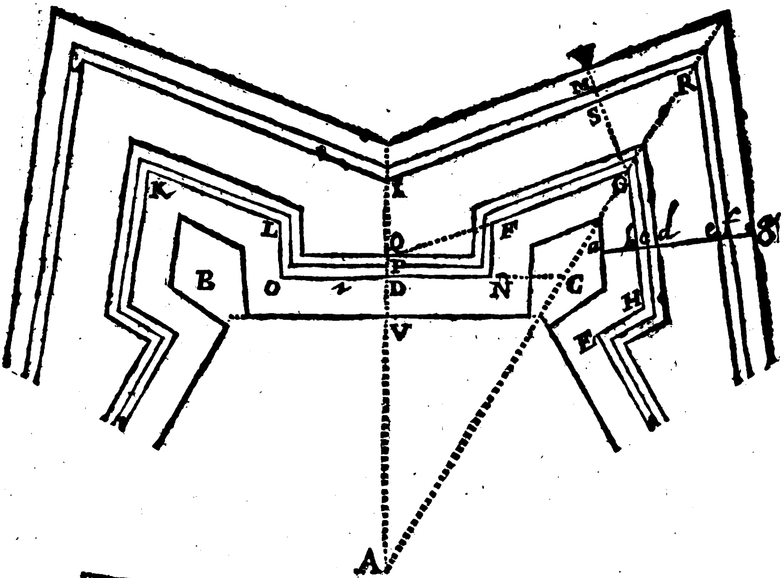
Shewing how and in what forme, the Rampire, and Parapets are to be raised, and the Ditch to be sunke.

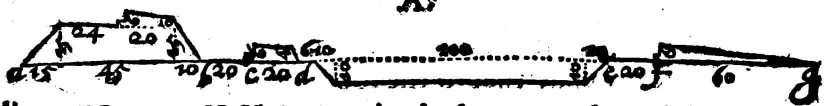
WE have shewed in the Chapter last before going, how to delineate the platforme of a Fort, and also how to stake out the same upon the ground, we will proceede briefely to touch the rest.

First then it is to be understood that that which you have drawne, as before we have shewed, namely the



lines





lines *K L. L O. O N. N F. F G. &c.* is the outer edge of the Rampire, (as in this figure above) which Rampire may be in breadth or thicknes inwardly 7. rods, or somewhat more or lesse as occasion requirs, for in a Fort of 12. sides or more, & of importance answerable, it maybe 10. rods, and in a Fort of 4 bulworkes, being of lesse importance if it be 5. rods, it may be sufficient, and in small skonces much lesse, which thickenesse is here represented by *D V*. so that the line drawne by *V*. doth represent the inward side of the Rampire, being in the curtaine, flanke, and front, every where parallell or equidistant to the outside of the Rampire before described; Yet sometimes the bulworkes are quite filled up, and (so it seemes best they should be,) because the assaults by myne or battery, are commonly made against them, but here we suppose the middle parts of them namely about *B*. and *C*. to be voyd.

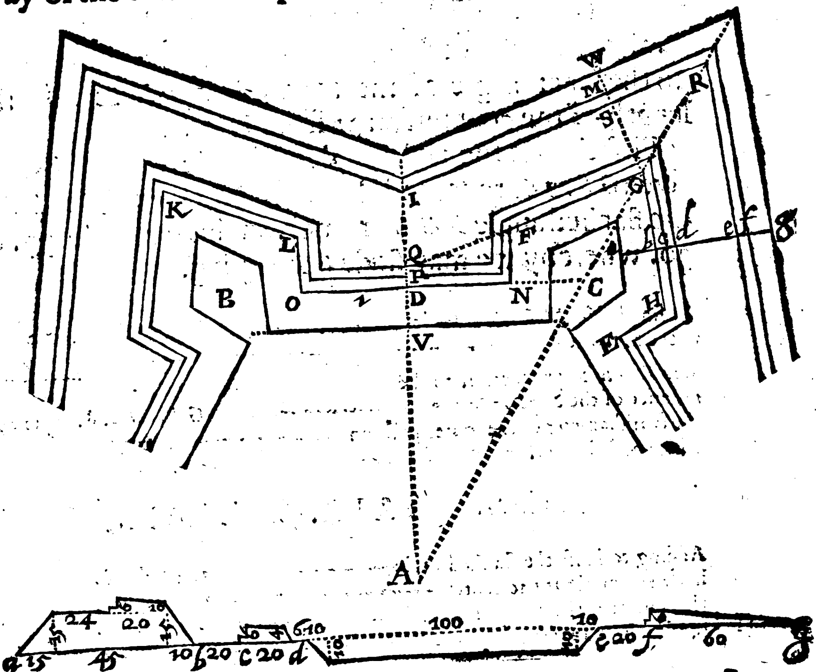
Next if you make a walke for the Rounds called a Fausse-bray, then without the body of the Fort, namely from the outer edge of the Rampire before described, measure two rods for the breadth thereof, and two rods more outward for the thickenesse of the parapet of the same Fausse-bray, and these may be either of them halfe a rod, more or lesse, as the place shall require, which spaces are here represented by *D P.* and *P Q.* and by the lines drawne by *P.* and *Q.* every where parallell to the outer edge of the Rampire, before described, in the fronts, flankes, and curtaines. Next without this parapet, namely from the foote of it to the side of the ditch you may leave halfe a rod or more for the brimme of the ditch, especially if it be in sandy or loose ground, that so the foote of the parapet may be the more firme. And these are the things to be set out within the ditch, which you are to marke out on the ground accordingly. The Port or Ports, are best to be made in the middle of the curtaine, for so they are defended from two flankes, and are to be placed as low as may be to avoyd any battery, that may be made against them, and a wooden bridge over the ditch, with gates and drawbridges in severall parts thereof.

Then may you set out the breadth of the ditch which may be 12. rods, or more or lesse, as occasion requires, for if the ground be low, so that you cannot digge deepe, by reason of the water, the ditch must be the larger, that there may be a sufficient quantity of earth

for

for the Rampire and Parapets, therefore to the front of the bulworke *F G*. and to the point *G*. being the angular point of the bulworke, raise the perpendicular *G S*. and because the faussebray with the parapet thereof is in breadth 4. rods, and in this example we make the ditch 12. rods broad, therefore make the line *G S*. 16. rods, and by the point *S*. draw *R S I*. the outer edge of the ditch, which here is parallel to the front of the bulworke *G F*. but is sometimes so drawne that it comes more inward against the middle of the curtaine at *I*. then at *R*. by a rod or two.

¶ Next without the ditch must be the coridor or covert way of the counterscarpe whose breadth from the side



 of

of the ditch may be two rods, or thereabouts, which is here represented by the space *S M.* and without that covert way, must be an argin or parapet 5. or 6. rods broad, represented by *M. W.* And all these namely the counterscarpe, or outer edge of the ditch, the covert way and the parapet thereof are in such sort to be continued round about the Fort, so that as we have shewed to draw one side from the point *I.* against the middle of the curtaine to the point *R.* against the angular point of the bulworke, the like is to be done for all the rest.

Now that the outer edge of the ditch *R S I.* may be the more truely drawne and set out, we may by the doctrine of triangles finde the distance from the angular point of the bulworke *G.* to the outer angle of the ditch *R.* also the distance from the middle of the curtaine *D.* to the inner angle of the counterscarpe *I.* as also the length of the counterscarpe from *I.* to *R.*

First then in the right angled triangle *G S R.* there is given *G S.* 16. rods, and the angle *S R G.* equall to halfe the flanked angle *F G C.* namely in this example 37. d. 36. whereby we may finde *G R.* saying.

As sine halfe the flanked angle	*G R S.* 37. d. 36.	0,2156.
to the breadth	*G S.* 160. foote.	2,2041.
so is *Radius* in proportion to the distance of the angular points	*G R.* 262. 8.	2,4197.
the semidiameter of the outer poligon	*A G.* 937. 4.	
which added together give the line	*A R.* 1200. 2.	

In the triangle A I R. *for the line* I R.

Adding to halfe the flanked angle	*I R A.* 37. d. 30.
halfe the angle at the center	*I A R.* 30. 00.
the summe is the complement of	*A I R.* 67. 30.
to two right angles or	180. 00.

Therefore

Therefore

As the sine of the angle	A I R. s.	67. d. 36.	0,0344.
to the lin: before found	A R.	1200.2.	3,0793.
so sine halfe the angle at the center	s. I A R.	30.06.	9,6989.
to the outer edge of the ditch	I R.	649. 5.	2,8126.

Lastly for I D.

As sine the angle	s. A I R.	67. d. 36.	0,0344.
to the line before found	A R.	1200. 2.	3,0793.
so sine halfe the flanked angle	s. I R A.	37.d. 36.	9,7844.
to the line	A I.	790. 8.	2,8981.
from which taking the lesser perpendicular	A D.	593. 4.	
there remaines the distance	D I.	197. 4.	

And so farre is that inner angle of the counterscarpe from the outside of the Rampire in the middle of the curtaine.

The true measure of these lines being thus found, they may the more exactly be set out.

And thus much touching the delineation of the platforme of a Fort, and the marking of it out upon the ground; we come next to speake of the height of the Rampire and parapets and of the depth of the ditch.

The Rampire and parapets wee suppose to be raised of earth taken out of the ditch; touching the forme of the workes, in height, depth, and scarpings; that it may be the better conceived, we draw the line *a b c d e f g.* crossing the front of the bulworke, ditch, counterscarpe, &c. at right angles, upon which line we may represent the breadth, heighth, depth, and scarpings,

 of

of all thē workes, which that it may be thē more sensible we draw here apart a longer line, *a b c d e f g.* and on this line by a scale so large, that feete and parts of feete may be well discerned, first set downe the breadth of the Rampire, from *a* to *b.* 70. foote, the breadth of the faussebray *b c.* 20. foote, the breadth of the parapet thereof *c d.* 20. foote, leaving without it 5. or 6. foote for the brimme of the ditch, and from thence set off the breadth of the ditch to *e.* 120. foote, and without that the breadth of the covert way *e f.* 20. foote, and without that the breadth of the Argin or parapet thereof *f g.* 60. foote, and thus you have expressed in this line, the breadth of all the workes to be made.

Then betweene the points *a.* and *b.* the Rampire is to be raised which in Forts of foure sides may be onely 12. foote high, but in a fort of 12. sides or more, some would have to be 18. or 20. foote high; in this example we make it 15. foote high, for the too great height of it may be prejudiciall to the defendants, especially when the assaylants shall approach neare the ditch. The Rampire is to be raised on either side scarping, namely on the outside, for every two foote that it riseth it may scarpe one, but here for every three foote that it riseth it scarpes two, so that the toppe of it being 15. foote, scarpes 10. foote, and in some sandy or loose grounds it had neede to scarpe more. But the inner side of the Rampire next the Fort scarpes more, namely for every foote that it riseth in heighth, it scarpes a foote, and being raised to his full height namely 15. foote, it hath also 15. foote scarpe, to the intent that the defendants may the more easily ascend the Rampire in all parts as occasion shall require, and thus

though

though the bottome of the Rampire *ab.* be 70. foote broad yet the upper superficies of it is but 45. foote broad, and these are the breadth height, and scarpings of the Rampire round about the Fort: upon the outside of the upper superficies of the Rampire, is raised a parapet, sometimes 24. sometimes 15. foote broad or more or lesse, here we make it 20. foote broad below, and on the inner side 6. foote high, with a foote scarpe, but outwardly not above foure foote high, within which parapet is a banke or foote pase round about, being sometimes two but here three foote broad, and a foote and halfe high. In like sort is raised the parapet of the faussebray, and also that of the covert way, without the ditch, save that the outside thereof is slanting or scarping about 60. foote till it be even with the champion about; all which may sufficiently appeare by the figure *abcdefg.* which figure thus drawne wee may call the Section or Profile. Touching the ditch it is in this example 120. foote broad, and 10. foote deepe, either side of it scarping also tenne foote as by the Section appeares. And thus much of the workes to be made, and in what forme, now touching the manner, we will briefely set it downe out of S. *Marolois* his Fortification as followeth.

In the Netherlands when such a worke is to be resolved on, the Engineir drawes such conditions as are to be observed, for the more speedy accomplishment of the worke, the time when it shall begin, and when it ought to be finished, the number of workemen to bee usually imployed, whether the foundation be to be piled and how: how many feete he will allow without

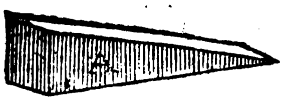
the

the foote of the Rampire for the Faussebray and its parapet and for the brimme of the ditch, the thicknesse or breadth of every of them, what scarpe is to be given within and without, according to the fastnesse or loosenesse of the earth: how many fagots shall be layd if the ground be sandy. In the parapet of the faussebray and in the Rampire, the height and scarpings inward and outward; the breadth depth and scarpings of the ditch, and all things else appertaining to the worke, and so gives notice in the townes nere adjoyning, that upon such a day there are such and such workes to be let out to such men as will undertake and performe them, best and best cheape. And upon the day appointed the undertakers being assembled, and the conditions and covenants read, according to which the businesse is to be done. Question is made who will undertake, and at the lowest price, one of the undertakers offers to doe it so, another it may be for lesse, and so at length till none will undertake it cheaper. Then under the articles of the conditions and covenants, he writes that such an one hath undertaken that businesse upon those conditions, for such a summe; sometimes two or three men undertake the whole worke, and they all signe to the Articles, as also the Lords commissarises, and the Engineir, and then the businesse begins; and usually the undertakers are bound by the sayd Articles and contracts to finde the materialls necessary for the sayd businesse; which they receive of the keepers of the Magasins or store, respectively for that use, or otherwise under their custody to be againe restored. Then the sayd master undertaker, divides his men according as he conceives the quality of the businesse

doth

doth require: so many he assignes to digge, so many to drive the Carts, and others to lay the earth even: for at the beginng of the worke it seemes best to carry away the earth which is digged on the outside of the ditch, with horse and cart, to lay the foundation or bottome of the Rampire; and not with wheele-barrowes, as they doe afterwards when the worke begins to be raysed to its height, and the ditches grow deepe, for then it is very hard to use horse and cart because the horses spoyle the worke, and cannot be so conveniently employed as wheele-barrowes, which are driven upon plankes in good order and readinesse, as any man may judge that hath beene present, where such workes have beene made.

If the outside of the Rampire be raysed with turfe, it is to be understood that they be usually 4. or 5. inches in breadth and as much at one end in thickenesse, and 14. or 15. inches long, but at the other end waxing sharpe like a wedge, to the intent that betweene them there may be put a little earth, to make them hold the faster to the body of the Rampire, their forme you may conceive by the figure *A*. These turfes must be so



layd that in every range upward, the middle of every turfe above, may lye justly upon the joyncture of every two turfes of the range next below, and so much aslope as is answerable to the scarping intended and agreed upon, for the better performance whereof, they have a triangular instrument, the sides thereof 2. or 3. foote long, and the

the angle contayned of those sides, such as is answerable to the scarping intended, so as hanging a plumbline parallell to one side, the other side may be agreeable to the sayd scarping. If you lay any fagots in the Rampire, they must be so layd that their ends may reach the former turfes, to wit, from halfe foote to half foote, for every halfe foote of earth must bee a range of fagots, and so continuing till the worke be finished. Vpon the top of the Rampire the parapet is to be raised with such scarpe and breadth as is before determined, (all in such sort as before,) raysing it with turfes as above sayd. If there be neere at hand any good earth, that is fat and clammy, then instead of turfes you may make a crust, of 3. or 4. foote or more, beating it well with a bat, made for that purpose, and shaping it with such scarpe as is agreed upon: in which crust they sow a certaine herbe, or the rootes thereof, called in *Flemish Queeckruit*, in *Latine Gramen*, and in *French Herbe de prau*, which roote hath the property to spread it selfe throughout the Rampire, and bindes it together in such sort, that it makes the sayd crust endure very long, and become almost perpetuall. Also upon the sayd crust, they sow the seedes of Oates, Hay, or a certaine roote they call *Zevenbladlren*, or the roote of seven leafed grasse, which is also very good, but these leaves doe not so cover the outside of this crust, as doth the foresayd herbe; for which cause his excellency hath of late yeares, repaired all the Fortifications, with such a crust without turfe, because experience shewes that the sayd turfes doe not bind together with the rest of the earth as that crust doth, which they use to moysten, that it may mixe and cleave the better to

Gramen, an herbe called Dogs-tooth Herbe *de Prau*. An hearbe Meddow-grasse.

the

the earth of the Rampire, being so very commodious and of good expedition: thus farre *Morolois*.

And because some things touching the raysing the with turfe, and laying fagots, are more distinctly set downe by our Countrey man Mr. *P. Ive*, (who seemes to have had experience in what he writes,) I have thought good to set downe his words as followeth.

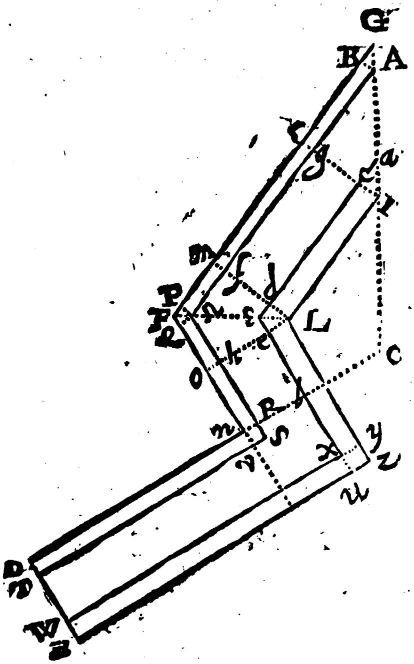
The manner of the worke is this, the turfe must bee cut like a wedge of 12. or 14. inches long, and 5. or 6. inches broad, equidistant, the one end 4. or 5. inches thicke, and the other sharpe, and these turfes would be taken in the best ground, that lyeth neere about the Fort, and must be cut with a long sharpe spade, of 5. or 6. inches broade, and 14. inches long, which must bee well steeled, and kept very sharpe, and the turfe must be carryed and handled without breaking, and layd in the worke, the great end outwards, and the grassie side downeward, and scarping one foote in 5. or 6. feete; the Rampire behind the turfe rising with the earth that is throwne out of the ditch, as fast as the face of the worke riseth; (And when the face is raised the height of 5. turfes, and the earth behind it layd even, and spread almost as broad as the Rampire is intended, (which may be 20. 30. or 40. foote or more or lesse, as the earth throwne out of the ditch will make it) or at least so broad, as it is thought that the wood will lye: for to say truth, to throw downe the earth, or to spread it too broad before the wall be raysed, were a point of no great discretion) stretch a line and pare the turfe even with a sharpe Spade, but scarping according to the first scarpe you layd them at, and then lay a row of fagots, which fagots must be 8. or 9. foote long, more or lesse as the wood will give them, but not thicker than that you may almost gripe them betweene your two hands, the great end of the wood lying all one way in the fagot, which end must be stamped against the ground, that it may lye even in the wall, and must be bound with three bonds, and layd in the worke, the great ends outwards, one inch over the turfe, and must be thrust up fast and close, the one to the other, but not layd thicker than one fagot at once; and upon the small end of those first layd fagots, must other fagots be layd whose small ends must over-lap the small ends of the sayd first fagots, some three foote and a halfe, or thereabouts; and upon the great ends of these second fagots must a third fagot be layd, whose small ends must likewise over-lap the great ends of the sayd second fagots, as the small end of the second did the small ends of the first (and where wood is plenty having hast to raise the worke, lay a fourth fagot in like manner) which being done, raise againe the face of the worke five turfes higher, paring it by a line as is aforesayd, and raysing the earth behind them as before, and then lay another row of fagots, and thus continue the worke untill it riseth so high as you intend it. Where wood is scarce, there use none but in the bulwork onely, and there as little as you may, but onely to stay the face of the bulworke; and raise the face of the curtaine with turfes onely, giving them somewhat the more scarpe, or for a need use no wood at all.

CHAP.

CHAP. IX.

Of the quantity of earth for raising the Rampire and Parapets.

WHether the worke be let out at a certaine price to undertakers, as aforesayd or otherwise, it is required to know what quantity of earth will serve for all or any of the workes intended, wherefore let this figure be a twelfth



part of the hexagonall Fort before mentioned, *Chap.* 8. and let the line *G F.* represent the front 280. foote, *F n.* the flanke 111 ¼ foote, or 111. 25. *D n.* halfe the curtaine 210. foote: *D H.* the breadth of the Rampire at the foote which (as before we shewed) is in this example 70. foote, *D T.* the outward scarping 10. foote, *W H.* the inward scarping 15. foote, and so the breadth of the Rampire at the toppe or besides the scarpings *T W.* 45. foote. First then we will measure the crassitude of the Rampire without the scarpings as if it were above and beneath onely 45. foote broad, and afterwards cast up the content of the scarpings, both without and within, which added to the former will give us the solid content of this part of the Rampire, from the middle of the curtaine to the angular point of the next bulworke, which being knowne we shall easily finde the content of the whole Rampire round about, first therefore we will here shew

To find how much the Rampire is about at the foote, and also at the toppe, within and without.

For the line BG.

As *Radius* is in proportion
to tang. compl. halfe the flanked angle —— *B G A.* 37. d. 36. t.c. 10,1150.
so is the outward scarpe —————— *A B* 10. foote. 1,0000.
to the line —————————— *BG.* 13. 03. 1,1150.

For the line K G.

As *Radius* is in proportion
to tang. compl. halfe the flanked angle —— *B G A.* 37. d. 36. t.c. 10,1150.
so is the thicknesse of the Rampire —————— *I K.* 70. foot. 1,8451.
to the line —————————— *K G.* 91. 22. 1,9601.

For

For the line ca.

As *Radius* is in proportion
to tang. compl. halfe the flanked angle— —— *c a l.* 37. d. 30. t. c. 10,1150.
so is the inward scarpe ———————— l C. 15. foote. 1,1761.
to the line ———————————— *ca.* 19. 55. 1,2911.

For the line FP.

As *Radius* is in proportion
to tang. compl. halfe the angle of the shoulder. *P F* ♌. 56. d. 15'. t. c 9,8249.
so is the outward scarpe ——— ———————— *P A.* 10. foote. 1,0000.
to the line ———————————— *F P.* 6. 68. 0,8249.

For the line. F *m.*

As *Radius* is in proportion
to tang. compl. halfe the angle of the shoulder *m F L.* 56. d. 15. t. c. 9,8249.
so is the breadth of the rampire ———————— *L m.* 70. foote. 1,8451.
to the line ———————————— *F m.* 46. 77. 1,6700.

For the line ed.

As *Radius* is in proportion
to tang. compl. halfe the angle of the shoulder —*d e* L. 56. d. 15'. t. c. 9,8249.
so is the inward scarpe ———————— *L d.* 15. foote. 1, 1761.
to the line ———————————— *e d.* 10,02. 1,0010.

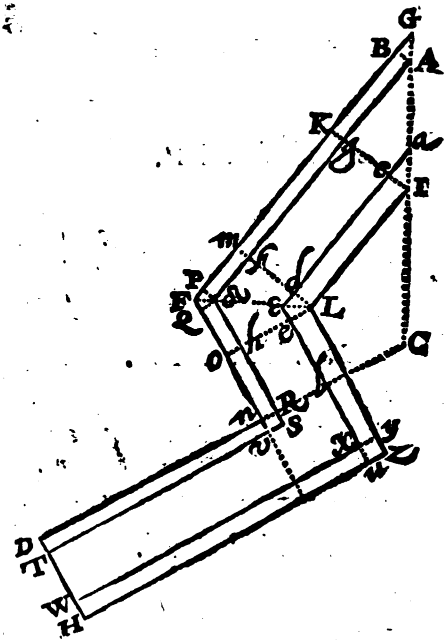
For *A* ♌.

Thus then we have the line— ———————— *B* G. 13. 03.
and the line- ———————— *F P.* 6. 68.
the summe of them both is ———————— 19 71.
which substracted from the front— ———————— *F G.* 280. foote.
there remaines the line ———————— *A* ♌. 260. 29.

For ♌ S.

And if from the flanke ———————— *F M.* 111. 25.
we substract *F Q* which is equall to ———————— *F* P. 6. 68.
there remaines the line ———————— *Q n.* 104. 57.
whereto adding the scarpe— ———————— *N v.* 10.
we have the line ———————— *A* ♌ 114. 57.

For



For S T.

And if to halfe the curtaine	n N. 210. foote
we adde the scarpe	N R. 10. foote.
we have the line	S T. 220. foote.
to which adding the line	♌ S. 114. 57.
also the line	A ♌ 260. 29.
we have the outer compasse	A ♌ S T. 594.86.

For the line L I:

We found before the line	K G. 91. 22.
and the line	F m. 46 77.
the summe of them both is	137. 99.
which substracted from the front	F G. 280. foote.
there remaines the line	L I. 142. 1.

For

For the line LZ.

Againe the line *FO.* being equall to ———— *F N.* 46.77.
substracted from the flanke ———— *F N.* 111.25.
there remaines the line ———— *O N.* 64.48.
whereto adding the thickenesse of the Rampire ———— 70.
the summe is the line ———— *L Z.* 134.48.

For HZ.

And if to halfe the curtaine ———— *D N.* 210. foote.
we adde the thickenesse of the Rampire ———— 70. foote.
we have the line ———— *H Z.* 280. foote.

For the line a e.

And seeing to the line *L Z.* is equall ———— *d c.* 142. 01.
to which adding the line ———— *c a.* 19.55.
and also the line ———— *e d.* 10.02.
the summe of these three is the line ———— *a e.* 171.58.

For the line EX.

Also to the line *L Z.* before found is equall ———— *e u.* 134.48.
whereto adding ———— *E e.* 10.02.
the summe is the line ———— *E u.* 144.50.
from which taking the scarpe ———— *X u.* 15.00.
there remaines the line ———— *e X.* 129.50.

For the line WX.

Also we found before the line ———— *H Z.* 280. foote.
from which substracting the scarpe ———— *u Z.* 15. foote.
there remaines the line ———— *W X.* 265. foote.
whereunto adding the before found ———— *a E.* 171.58.
as also the line before found ———— *e X.* 129.50.
we have the inner compasse ———— *a e X W.*

For the solid content of the Tere-plein or of the Rampire the scarpings excepted.

Thus we have the outer compasse of the upper part of the Rampire	A Ω S T. 594. 86.
Also the inner compasse	a ε X W. 566. 08.
the summe of them both is	1160 94.
the halfe whereof is	580. 47. 2,7637798.
which multiplyed by the breadth	T W. 45. 1,6532125.
and the product by the height of the Rampire	15. 1,1760912.
produceth the solid content of the Rampire the scarpings excepted, namely	391817. feete. 5,5930835.

Note.

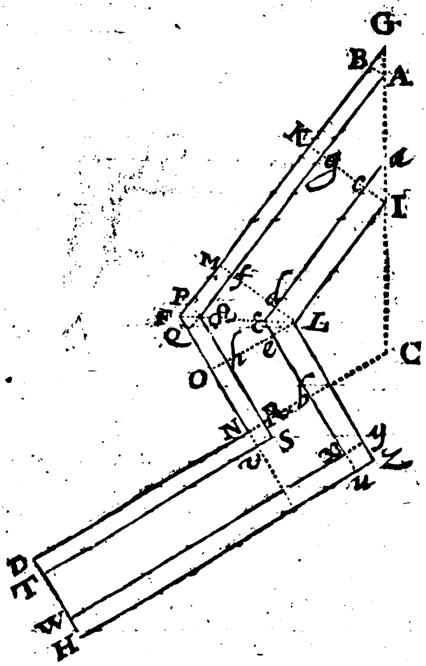
This product you may finde multiplying after the ordinary manner; or if you worke by logarithmes, you have here an example, but if the numbers be very great, as this last which exceeds all tables of logarithmes, you may worke by the part proportionall, as we have shewed Chap. 2. Booke 1. *of* Plaine triangles.

For the solid content of the scarpings.

Againe to the line	A Ω. 260. 29.
adding the line Ω R. or	Q N. 104. 57.
and also the line	N D. 210.
The summe of them is	574. 86 2,7595621.
which multiplyed by the outward scarpe	T D. 10. 1,0000000.
produceth the area	5748. 60. 3,7595621.

Furthermore

Furthermore to the line	IL. 142. 01.	
adding the line	eX. 129. 50.	
and also the line	WX. 265.	
the summe is	536. 51.	2,7955778.
which multiplyed by the inner scarpe	WH. 15.	1,1100912.
produceth the area	8047. 65.	3,9036690.
whereunto adding the area before found	5748. 60.	
the summe is	13796. 25.	
the halfe whereof is	6898. 12.	3,8387307.
which multiplyed by the height of the Rampire	15.	1,1760912.
produceth the solid content of the outward and inward scarpings of the Rampire,		5,0148219.
the pyramids in the corners excepted	103472. cub. feete.	



For the Pyramides in the angles.

Also multiplying the line —— BG. 13.03. 1,11502.
by the outward scarpe —— AB. 10. 1,00000.
the product is —— 130.30. 2,11502.
halfe whereof is the area of the triangle —— ABG. 65.15.
secondly the line —— FP. 6.68. 0,82489.
multiplyed by the outward scarpe —— ℞P. 10. 1,00000.
produceth the area of the trapezium —— ΩPFQ. 66.80. 1,82489.

The area of the square —— nRSv. is. 100.
which doubled because there are two pyramides is —— 200.

Also multiplying the inward scarpe —— Xu. 15. 1,17609.
by the inward scarpe —— Xy. 15. 1,17609.
produceth the area of the square —— Xuzy. 225. 2,35218.

And we found before the line —— ed. 10.02. 1,00086.
which multiplyed by the scarpe —— dL. 15. 1,17609.
produceth the area of —— eedL. 150.30. 2,17695.
which doubled is twice —— eedL. 300.60.

Lastly having found before the line —— ea. 19.55.
which multiplyed by the line —— Ic. 15.
produceth the area of twice —— Iea. 293.25.

Thus then the area of —— ABG. 65.15.
the area of —— ΩPFQ. 66.80.
the area of twice —— nRSv. 200.
the area of —— Xuzy. 225.
the area of twice —— eedL. 300.60.
the area of twice —— Iea. 293.25.
The summe of all these is —— 1150.80. 3,06100.
multiplyed by a third part of the altitude —— 5. —— 0,69897.
produceth the solid content in feete of all these
pyramids in the corners —— 5754. 3,75997.

Thus

Thus then the solid content of the Rampire
the scarpings excepted is ———————— 391817. foote.
the solid content of the scarpings the
pyramids in the corners excepted is ———— 103472.
the solid content of the pyramids in
the angles or corners is ———————— 5754.
the summe of all these is the solid content
of this part of the Rampire in cubicke feete ———— 501043.
which doubled is the solid content of one
bulworke and one curtaine namely ———— 1002086.
And this multiplyed by 6. because this fort
hath 6. bulworkes ———————— 6.
produceth the solid content of the whole
Rampire round about in cubicke feete ———— 6012516.

The Parapet of the Rampire.

And thus as we have found the solid content of the Rampire in cubicke feete, we may in like manner finde the content of the Parapet of the Rampire, if you will take that paines: But considering that the scarpings thereof within and without are very little, the height also not exceeding 6. foote; it may suffice if we finde the middle length of it by taking halfe the summe of the outward and inward perimeter, and that multiplyed in the area of the Section, or Profile of the Parapet will produce neere hand the solid content of the Parapet.

First then considering that the foote of the Parapet is 10. foote within the outer edge of the Rampire, (the Rampire having in this example 10. foote scarpe, before it riseth to the foote of the Parapet) therefore let the lines, *T S* & *A*. represent the outer foote of the Parapet, and because the inner foote is parallell thereto, therefore (to avoyd multiplicity) let us suppose the inner foote of the Parapet to be represented by the

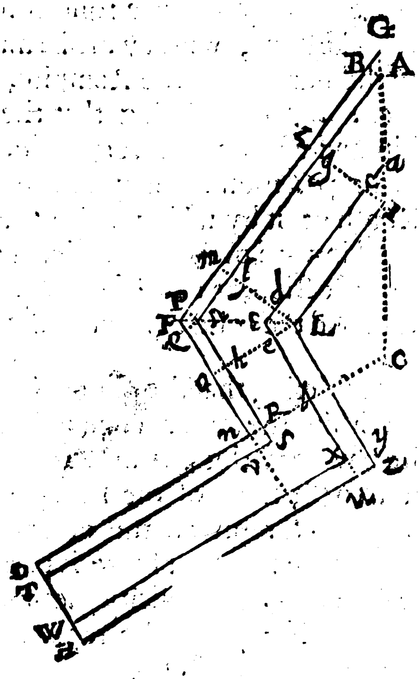
 lines

lines *Hz LI*. and supposing the breadth of the Parapet *TH*. or *gI*. to bee 20. foote, we have before found.

The line ———————————————— *A* ♌. 260. 29.
The line ———————————————— ♌ *S*. 114. 57.
The line ———————————————— *ST*. 220. foote.

For the line LI. *and first for* A g.

As tangent halfe the flanked angle ——— *g AI*. 37. d. 36. t. c. 10,11502.
to the breadth of the parapet ——————— *Ig*. 20. foote. 1,30103.
so is *Radius* in proportion
to the line ——————————————— *Ag*. 26. 06. 1,41605.



For

For f ♌.

As true halfe the angle of the shoulder —— f ♌ L. 56.d. 15'. t. c. 9,82489.
is the breadth of the parapet —————— f L. 20. foote. 1,30103.
so is *Radius* in proportion
to the line ———————————— f ♌. 13. 36. 1,12592.
whereto adding the line ———————— A g. 26. 06.
the summe is ———————————— 39. 43.
which substracted from ——————— A ♌. 260. 29.
remaines f g. being equall to ———— L I. 220. 86.

For the line L z.

Againe from the line —————————— ♌ S. 114. 57.
substracting ♌ h. equall to —————— f ♌. 13. 36.
there remaines the line —————— h S. 101. 21.
whereto adding the thicknesse of the parapet ———— 20.
the summe is the line ——————— L z. 121. 21.

For H z.

And if to the line ——————————— S T. 220.
we adde the thicknesse of the parapet ———— 20.
we have the line ———————————— H z. 240.

Thus then we have the lines about the outer foote of the parapet ——————— { A ♌. 260. 29. / ♌ S. 114. 57. / S T. 220. 00. }

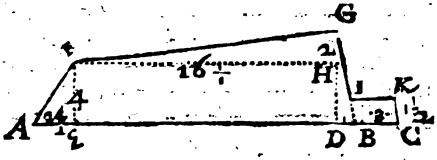
And also the lines about the inside of the parapet { L I. 220. 86. / L z. 121. 21. / H z. 240. 00. }

The summe of them all is ——————— 1176. 93.
the halfe whereof is ———————— 588. 46.

Which is the meane length of the parapet from the middle of the curtaine to the angular point of the bulworke.

Now for the area or superficiall quantity of the Profile

file or Section of the Parapet, suppose it be as in this figure. Wherein let the foote of the parapet here represented by *A B*, be in breadth 20. foote, the breadth



of the banke or foote-pace within the parapet *B C*. 3. foote, the height of that banke 1 1/2 foote, the height of the inner side of the Parapet *D G*. 6. foote. the height of the outer side *E F*. 4. foote, the outward scarpe *A E*. 2 1/2 foote, the inward scarpe *D B*. 1 foote.

Then is the line F H. *or* ——— E D. 16.5.
which multiplyed by the height D H. *or* ——— F E. 4.
produceth the area of the long square F E D H. 66. f. sq.

Also the scarpe ——— A E. 2. 5.
multiplyed by halfe the height 1/2 ——— F E. 2.
produceth the area of the triangle ——— F A E. 5. f. sq.

Thirdly the line ——— F H. 16. 5.
multiplyed by halfe the height 1/2 ——— G H. 1.
produceth the area of the triangle ——— F G H. 16.5.

Fourthly the scarpe ——— D B. 1. foote.
multiplyed by halfe the height 1/2 ——— G D. 3. foote.
produceth the area of the triangle ——— G D B. 3. sq. feet.

Lastly

Lastly the breadth of the banke —— —— B C. 3. foote.
multiplyed by the height thereof —— —— B I. 1.5.
produceth the area of the romboydes — I K C B. 4.5.

The summe of these five is the area of the
whole section in square feete — A F G I K C. 95.1,97772.
which multiplyed by the meane length of
the parapet —— —— —— —— 588.46.2,76972.
produceth in cubicke feete —— —— 55904.4,74744.

Which is neere hand the solid content of the Parapet, from the middle of the curtaine to the angular point of the next bulworke.

Therefore being doubled it is the solid content of the Parapet for one curtaine and one bulwork. 111808.
And because this Fort hath 6. bulworkes
therefore if we multiply the same by —— —— 6.
the product is in solid feete —— —— —— 670848.

Which is (neere hand) the solid content of the Parapet of the Rampire round about the Fort.

If you desire the solid content of the Parapet more exactly, you may worke after the forme of the example before shewed, in casting up the content of the Rampire. And in like manner you may doe for the solide content of the Parapet of the Faussebray, and of the counterscarpe or covert way, which forasmuch as they may bee easily conceived by these examples, wee passe them over and proceede to other things.

To finde what quantity of earth will serve to make the Rampire or Parapet, 100. foote long or more or lesse.

The area of the Section of the Parapet we found before to be of square feete ——— 95.
which multiplyed by the length given ——— 100.
produceth in cubicke feete ——— 9500.

And so much earth will serve to make the Parapet in length 100. foote.

And seeing the foote of the rampire is in breadth 70. foote.
and the upper part of it in breadth ——— 45.
the summe of these is ——— 115.
The halfe whereof is the meane breadth of the Rampire namely ——— $57\frac{1}{2}$.
which multiplyed by the height of the Rampire — 15.
produceth the area of the Section of the Rampire in square feete ——— $862\frac{1}{2}$.
which multiplyed by the length given ——— 100.
the product in cubicke feete is ——— 86250.

And so much earth serves to make the Rampire 100. foote long.

To finde what quantity of earth will raise the Rampire to any height assigned.

For brevity and perspicuity we will here as in other places, runne the example along with the rule, wherefore let it be required to finde what quantity of earth will

will raise thē Rampire 6. foote high, and 100. foote in length. And forasmuch as the Rampire in rising 15. foote, scarpes 25. foote, therefore in rising 6. foote it will scarpe 10. foote.

Therefore as

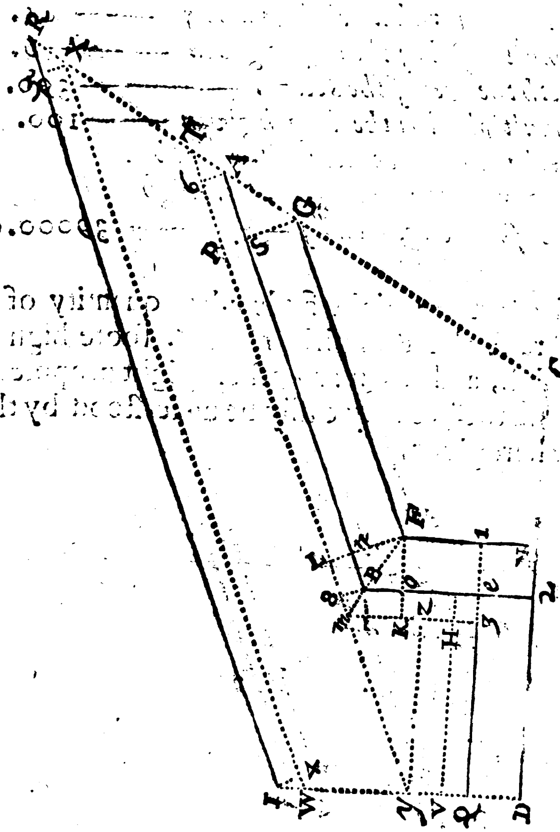
The breadth of the Rampire at the foote is —— 70. foote.
so being raysed 6. foote, the breadth is —— 60.
the summe of these breadths is —— 130.
the halfe whereof is the meane breadth
of the Rampire for that height, namely —— 65.
which multiplyed by the height given —— 6.
produceth the area of the Section —— 390. f.sq.
which multiplyed by the length given —— 100.
produceth the solide content of the earth
serving to raise the Rampire 6. *foote high*
and 100. *foote long, namely* —— 39000. cub. f.

In like sort we might finde what quantity of ēarth would raise the Rampire, from 6. foote high to 12. foote high, and so for any other height proposed, but these and the like may easily be understood by the example here given.

CHAP. X.

Of the Capacity or solide content of the Ditch, and in what time it may be digged.

THe ditch may be 140. foote broad, sometimes more sometimes lesse, as occasion requires: For if the ground be low, that it cannot bee



digged deepe by reason of water, the ditch must bee the broader that there may be earth enough for the Rampire and Parapets, if the ditch be dry it must be the deeper, and have the lesse scarpe. In this example wee make the breadth of the ditch at the toppe to be 120. foote, and at the bottome 100. foote, the depth 10. foote, and the scarping on either side 10. foote. Now then according to what wee have before sayd, if there be a Faussebray and a Parapet thereto, the inner edge of the ditch, will be distant from the outter edge of the Rampire, 30. 40. or 50. foote according to the breadth of those workes. Let it here be distant 40. foote, so that in this figure let *D N F G.* represent the outward foote of the Rampire, *Q S B A.* the inward side of the ditch, *I R.* the outside of the ditch.

Now for finding the capacity of the ditch; first (as we did before for the solid content of the Rampire) we will finde the compasse of the ditch, on the outside and on the inside: secondly the perpendicular capacity of the ditch, according to the least breadth of the ditch, which is at the bottome; thirdly the content of the scarpings, and lastly of the pyramids in the angles.

PROBLEME. I.

To finde the inward and outward compasse of the ditch.

There is already knowne
The halfe curtaine ———————— *D N.* 210. *foote.*
the flanke ———————————— *F N.* 111. 25.
the front ———————————— *F G.* 280.

 And

And there is required the compasse of the ditch on either side.

First for the outside of the ditch —— *I R. 649.5.*
we found it before *Chap.* 8.

We come therefore to the inward side —— *Q e B A.*

For the line B A. *and first for* A S.

As tang. halfe the flanked angle —— *S A G.* 37.d. 30'. t. c. 10,11502.
to the distance of the ditch from the Rampire —— *S G.* 40. foote. 1,60266.
so is *Radius* in proportion
to the line —— *A S.* 52.13. 1,71708.

secondly for B n.

As tang. halfe the angle of the shoulder —— *n B F.* 56.d.15. t. c. 9,82489.
to the ditch from the Rampire —— *n F.* 40. foote. 1,60206.
so is *Radius* in proportion
to the line —— *B n.* 26.73. 1,42695.
whereto adding the line before found —— *A S.* 52.13.
as also *n S.* equall to the front —— *F G.* 280.
the summe is the line —— *B A.* 358.86.

For the line B e.

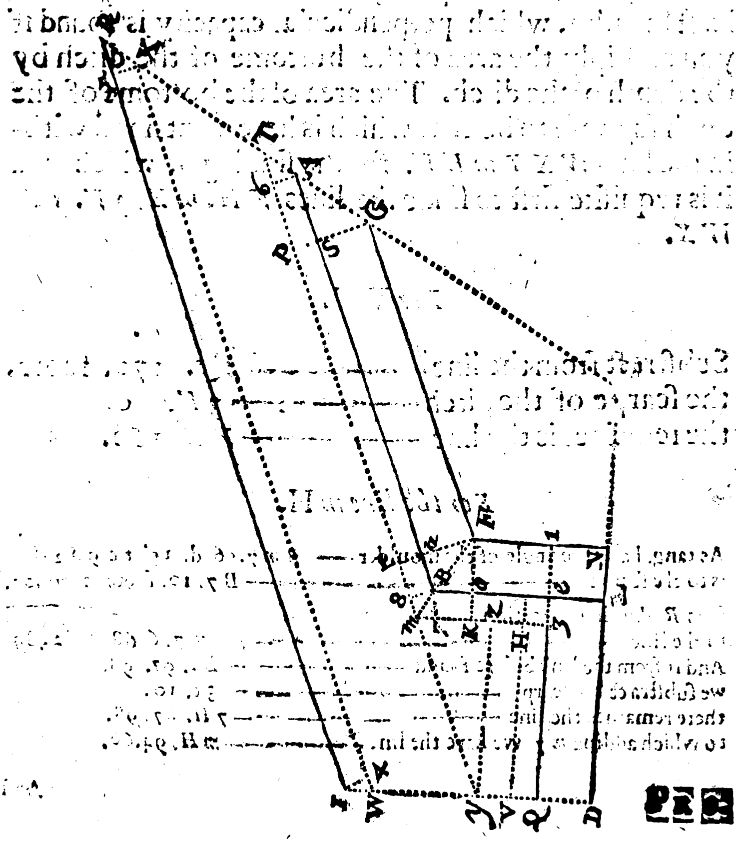
And if we substract from the flanke —— *F N.* 111.25.
the distance of the ditch from the Rampire —— *I e.* 40. foote.
there remaines *F* I. being equall to —— *O e.* 71.25.
whereto adding *B O.* which is equall to —— *BN.* 26.73.
the summe is the line —— *B e.* 97.98.

For

For the line Qe.

Lastly substracting from halfe the curtaine	D N. 210. foote.
the distance of the ditch from the Rampire	2 N. 40.
there remaines D 2. equall to the line	Qe. 170.
whereto adding the line	Be. 97. 98.
and also the line	B A. 358.86.
the summe is the compasse	Qe B A. 626.84.

which is the twelfth part of the inward compasse of the ditch.



PROBLEME. II.

To finde the perpendicular capacity of the ditch according to the least breadth thereof which is at the bottome, and first the lines thereto requisite.

BEcause the ditch is scarping and narrower at the bottome than at the toppe, you may first search the perpendicular capacity thereof according to its least breadth, which perpendicular capacity is found if you multiply the area of the bottome of the ditch by the depth of the ditch. The area of the bottome of the ditch suppose to be that which is here contained within the lines *W X T m H V*. for the finding of which area it is requisite first to finde the lines *V H. m H. y V: y T. W X.*

For V H.

Substract from the line ——— ———	*Q e.* 170. foote.
the scarpe of the ditch ——— ———	3 *H.* 10.
the remainer is the line ——— ———	*V H.* 160.

For the line m H.

As tang. halfe the angle of the shoulder ——	*B m* 7. 56. d. 15'. t.c	9,82489.
is to the scarpe ——— ——— ———	*B* 7. 10. foote.	1,00000.
so is *Radius* in proportion to the line ——— ——— ———	*m* 7. 6. 68.	0,82489.
And if from the line before found ——— ———	*B e.* 97. 98.	
we substract the scarpe ——— ———	3 *e.* 10.	
there remaines the line ——— ———	7 *H.* 87. 98.	
to which adding *m* 7. we have the line ———	*m H.* 94.66.	

 And

And seeing the angle of the shoulder is ——— z m T. 112. d. 36.
the compl. thereof to 180. deg. is the angle ——— z m y. 67. 30.

For y V. and first for m y.

As the sine of the angle ——— z m y. 67. d. 36. s. 0,03438.
to the line y z. being equall to ——— V H. 160. foote. 2,20412.
so is *Radius* in proportion
to the line ——— m y. 173. 18. 2,23850.

Secondly, for m z.

As the sine of the angle ——— z m y. 67. d. 36. s. 0,03438.
to the same line ——— z y. 160. foote. 2,20412.
so sine complement the angle ——— z m y. 67. d. 30. s. c. 9,58284.
to the line ——— m z. 66. 27. 1,82134.
which substracted from the line ——— m H. 94. 66.
there remaines z H. equall to ——— y V. 28. 39.

For the line y T. and first in the triangle 6 A T.

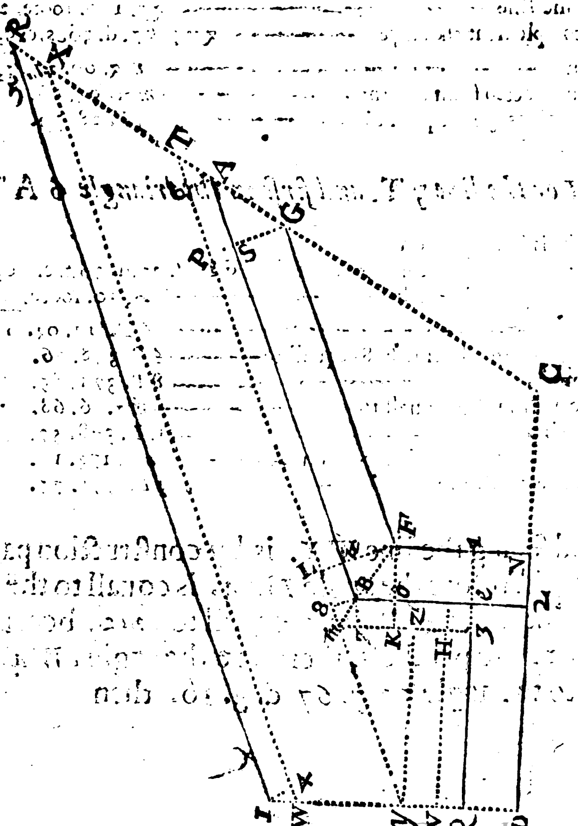
As *Radius* is in proportion
to tang. compl. halfe the flanked angle ——— 6 T A. 37. d. 36 t. c. 10,11502.
so is the scarpe of the ditch ——— 6 A. 10. foote. 1,00000.
to the line ——— 6 T. 13. 03. 1,11502.
whereunto adding the line 6, 8. equall to ——— A B. 358. 86.
the summe is the line ——— 8 T. 371. 89.
whereto adding 8 m. equall to ——— m 7. 6. 68.
we have the line ——— m T. 378. 57.
to which adding the line before found ——— m y. 173. 18.
we have the whole line ——— y T. 551. 75.

And seeing the line *W X*. is by construction parallell to *y T*. therefore the angle *I W* 4. is equall to the angle *I y m*. but the angle *I y m*. is equall to *y m z*. because *I y*. and *m z*. are parallels, therefore the angle *I W* 4. is equall to the angle *z m y*. 67. deg. 30. then

 For

For the line W X. I finde first W 4.

As the tangent of the angle ————	I W 4. 67. d. 36. t.c.	9,61722.
to the scarpe of the ditch ————	I 4. 10. foote.	1,00000.
so is *Radius* in proportion to the line ————	4 W. 4. 14.	0,61722.
And before we found 6 *T*. equall to ————	5. R. 13. 03.	
which substracted from the line ————	I R. 649. 50.	
there remaines *I* 5. equall to ————	4 X. 636. 47.	
whereto adding ————	4 W. 4. 14.	
the summe is the line ————	W X. 640. 61.	



For the area of the bottome, and the perpendicular capacity.

To the line	WX. 640.61.
adding the line	YT. 551.75.
the summe is	1192.36.
the halfe whereof is	596. 18.
which multiplyed by the breadth at the bottome	100. foote.
produceth the area of the figure	WXTy. 59618. sq. feete.

Againe.

we found before the line	mH. 94. 66.
and the line	yV. 28. 39.
the summe of them is	123. 05.
the halfe whereof is	61. 52½. 1,78906.
which multiplyed by	VH. 160. 2,20412.
produceth the area of the trapezium	myVH. 9844. 3,99318.
whereunto adding the area of	WXTy. 59618.
the summe is the area of the bottome of the ditch	VWXTmH. 69462. sq. feete.
which multiplyed by the depth	10. foote.
produceth the perpendicular capacity of the ditch, or the solide content of the ditch, the scarpings excepted, namely	694620. cub. feete.

For the Scarpings.

The length of the scarpings, namely of
- the line — VH. 160. foote.
- the line — H7. 87. 98.
- the line 8,6 — 358. 86.
- the line — X 4 — 636. 42.

the summe of these 4. lines is	1243. 31.
which multiplyed by the scarpe	10.
produceth the area	12433. 1.
the halfe whereof is	6216. 5.
which multiplyed by the depth	10.
produceth the solid content of the scarpings, the pyramids in the corners excepted, namely	62165. cub. feete.

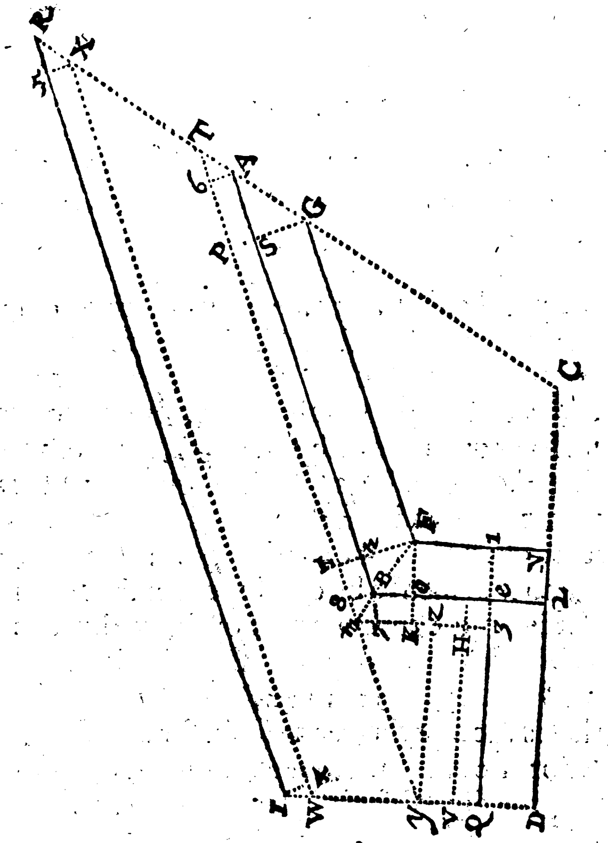
For the Pyramides in the corners.

The line	3 e. 10.	foote.
which multiplyed by the scarpe	3 H. 10.	foote.
produceth the area of the square	3 e z H. 100.	foote sq.

For the Trapezium. 7 B 8 m.

The line	7 m. 6. 68.
multiplyed by the scarpe	7 B. 10.
produceth the area of the base	7 B 8 m. 66.80.
which doubled because there are two pyramides is	133.60.
Also the line	6 T. 13. 03.
multiplyed by the scarpe	A 6. 10.
produceth twice the area of	A 6 T. 130. 30.
the halfe whereof is the area of	X 5 R. 65.15.
The line	4 W. 4. 14.
multiplyed by the scarpe	4 I. 10.
produceth twice the area of	W 4 I. 41. 40.

Thus then the area of	3 e z. H. is. 100. foote
the double area of	7 B 8 m. is. 133.60.
the double area of	A 6 T. is. 130.30.
the area of	X 5 R. is. 65.15.
the area of	W 4 I. is. 41.40.
the summe of all those area is	470.45.
which multiplyed by the depth	10. f.
the product is	4704. 50.
the third part whereof is the solide content of these pyramides	1568.17.
Thus then the perpendicular capacity of the ditch, the scarpings excepted, is	694620.
The scarpings of the ditch, the pyramides in the corners excepted is	62165.
The sayd pyramids in the corners	1568.
So the whole capacity of this part of the ditch is	758353.
Which doubled is the solide content of the ditch, for one bulworke and one curtaine	1516706.
And because this Fort hath sixe bulworkes therefore multiplying by	6.
we have the solide content of the ditch round about this Fort in cubicke feete	9100236.



But before we found the solide content of the
Rampire to be ———————————— 6012516
And the solid content of the Parapet on
The Rampire to be ———————————— 670848.
So that the solide content of the Rampire
and its parapet is ———————————— 6683364.
which substracted from the solide content of
the ditch there remaines ———————————— 2436872.

Which earth remaining may be employed to make the Parapet of the Covert way, and of the Faussebray, and for Cavalliers or mounts, otherwise if you make none, the ditch may be the lesse.

To estimate the charge to be bestowed, or the number of men, or time to be employed, in raising a Fort proposed.

BEfore you begin to breake ground, or to employ men in such a businesse as this, it is requisite that the Enginere cast up, as we have here shewed, the quantity of earth, that will serve to raise the Rampire and Parapets, and so of what breadth and depth, the ditch ought to be, that there may be a sufficient quantity of earth for that purpose: and that thus he may be able to give some neere estimate of the charge to be bestowed, and of the number of men to be employed for the accomplishing of it in time convenient. Touching the charge, S. *Marolois* saith (speaking of the Netherlands) that it is about 16. 20. 25. or 30. soulz for every 144. cubicke feete, that is (accounting tenne soulz for a shilling) 14s. or 20s. for 1000. cubicke feete, or more or lesse, according to the diversities of places and occasions. In *England* we have no such workes usually done, and therefore we cannot speake of any ordinary price, neither can there be any generall rule given for the time or number of men to be employed, in regard of the great diversity of grounds to be fortified, and other considerations, it may therefore suffice to shew how some neere estimate may be given.

As to give an estimate in what time a certaine number of mẽn may digg thẽ aforesayd ditch, containing 9100236. cubicke feete, of earth, it is requisite first to know what one man will digge in a day. When I was in the Fennes in *Lincolneshire*, I was informed by men of good experience there, that a man would digge and fill into a wheele-barrow in a day, 17. foote square of earth, and about 27. inches deepe, which is 650. cubicke feete of earth; I have beene enformed the like in other places, where they have wrought in Marsh land: S. *Marolois* in his booke of Fortification affirmes, that according to some of the best experienced in the Netherlands, a man working his best in earth that is fat and fast, may digge and fill into a wheele-barrow in a day 648. cubicke feete. But it may be, in any of these places, when they doe so much, besides the aptnesse of the earth, they take extraordinary paines. Let us therefore suppose that the most a man can ordinarily digge, and fill into a wheele-barrow of good earth, to be 500. cubicke feete in a day; then may 200. men digge, 100000. feete in a day, so that according to this account, 200. men may digge and fill away the foresayd ditch containing 9100236. cubicke feete in 91. dayes or thereabouts, for dividing 9100236. by 100000. the quotient 91. dayes and somewhat more not to be regarded. But if you finde the earth to be such, that a man cannot with ordinary paines taking, digge 500. foote in a day, you must make your account accordingly, as suppose I finde that a man digges but 300. foote in a day, and I would know in what time they would digge the foresayd ditch, I say, then by the rule of proportion

As

As 1. *Man.*
digges 300. foote ——————————— 2,47712.
so may 200. *Men.* ——————————— 2,30103.
digge 60000. foote ——————————— 4,77815.

Againe.

As 60000. foote ——————— *co. ar.* 5,22186.
is to 1. dayes worke.
so 9100236. foote. ——————————— 6,95993.
is 152. dayes worke almost. ——————— 2,18179.

Otherwise you may say by the rule of three reversed.

If ——————————— 500. foote a day.
require ——————— 91. dayes.
then ——————— 300. foote a day.
require ——————— 152. dayes worke almost.

In like sort you may estimate in what time any other number of men will be able to doe it, especially after some tryall made, for by reason of the great diversity of grounds, and other occurrents, this point cannot be alwayes determined without some tryall. Besides men doe usually much more when they take a businesse by the great (as they terme it) then when they worke by the day. Now looke how many Pyoners you employ to digge, so many you had neede to have with wheele-barrowes to carry it to the Rampire and Parapets, and others there to spread it, tread it, and lay it even, and to rayse the worke in its due forme, and this being diversly performed, sometimes with a face of turfe, sometimes of of earth ſowne with graſſe ſeede, ſometimes laying faggots or wood in the Rampire; ſometimes none, ſometimes a foundation to be layd (as in ſoft Oazie grounds) of timber or brick-worke &c. there is no generall rule to be preſcribed in this point, touching the certaine number of men to be employed.

CHAP. XI.

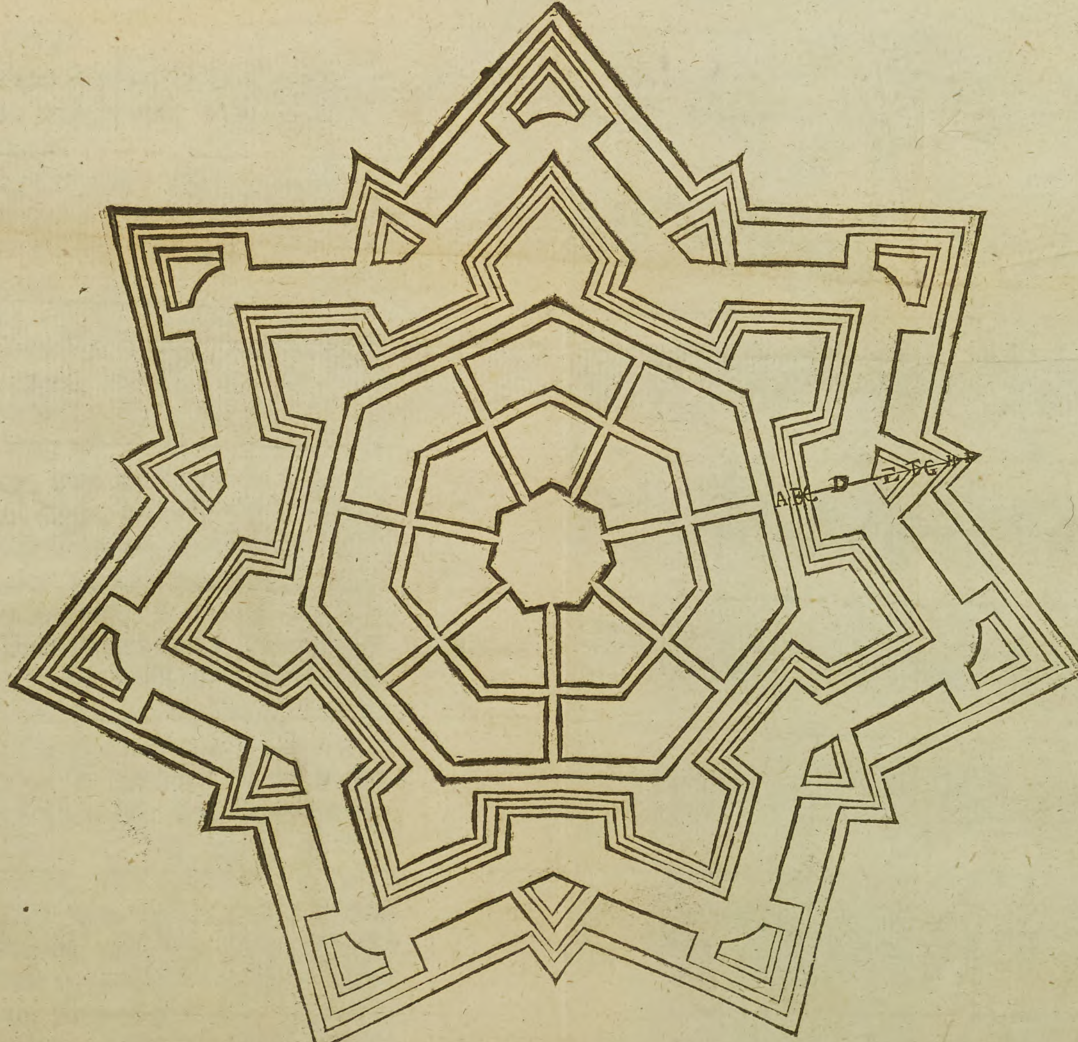
Of ſuch other workes as are ſometimes made in or about Forts of moſt importance.

WHen I began this Treatiſe I had no intent to have waded ſo farre in this part of Architecture military, as I have already done, but onely to ſhew therein the application of the Doctrine of plaine triangles, as it is performed by this late invention of Logarithmes, and indeede that had beene ſufficient to thoſe that have reade ſuch moderne Authors, as have more fully handled this ſubject in other Languages. But conſidering how little hath beene written hereof in our *Engliſh* tongue, and that the practiſe of it with us is very rare. I have beene ſomewhat larger than I intended, and here further have annexed this deſcription of a Fort of ſeven ſides, expreſſing therein ſuch other workes as are ſometimes made in or about the moſt compleate Forts that are uſually reared.

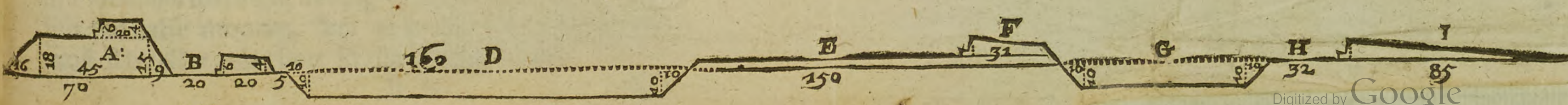
We have before ſufficiently ſpoken of the Rampire and its Parapet, here marked with *A.* as alſo of the walke for the Rounds or Fauſſebray *B.* and of the Parapet thereof *C*. as alſo of the ditch, here marked with *D*, and of the curtaines, bulworkes, fronts, flankes, ſcarpings, &c. to proceede therefore to the reſt. Next within the Rampire, betweene the Rampire and the houſes, there is a ſtreete left ſometimes 30. but here 40. foote broad, whereto the ſouldiers may retreate, or be put in array as occaſion requires, the other ſtreets are ſometimes 24. but here 30. foote broad, and in the middle is the market place, being of the ſame forme whereof the Fort is, namely of ſeven ſides, every ſide being 15. or 18. rods, the other ſpaces betweene the ſtreetes, are for the houſes of the inhabitants and ſouldiers.

On the outſide of the ditch, betweene every two bulworkes, and againſt the middle of the curtaine is placed a Ravelin, one of them being marked with *E*, and the reſt ſcituated in like manner, the two Fronts of every of theſe Ravelins may be 15. 20. or 25. rods, and theſe are ſo made on the edge of the ditch, that their inward angles are at the concourſe of the lines bounding the ditch; and that the Fronts of theſe Ravelins, might be the better defended, their outward angles are the more acute, inſomuch that they are flanked from all or the greateſt part of the Fronts of the bulworkes next unto them.

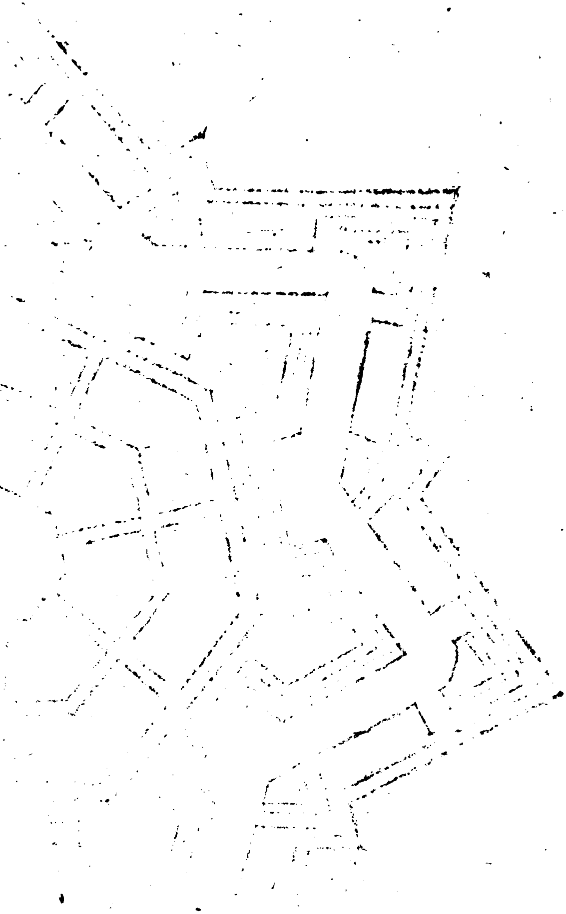
The Ravelin here marked with *E*. and ſo the reſt are raiſed above the champion (or levell whereon the Fort ſtands) 4. foote, and it ought not to be higher that it may not impeach the diſcovery of the champion about. And upon the Fronts of every of theſe Ravelins thus raiſed, you may make a Parapet 20. foote thicke, and 6. foote high, that ſo it may be Cannon proofe.



Place this Fort between fol. 126. and 127.



The Profill or Section.



proofe. The ditch betweene the Ravelin and the counterscarpe, may be 5. or 6. rods broad, and as deepe as you can conveniently make it.

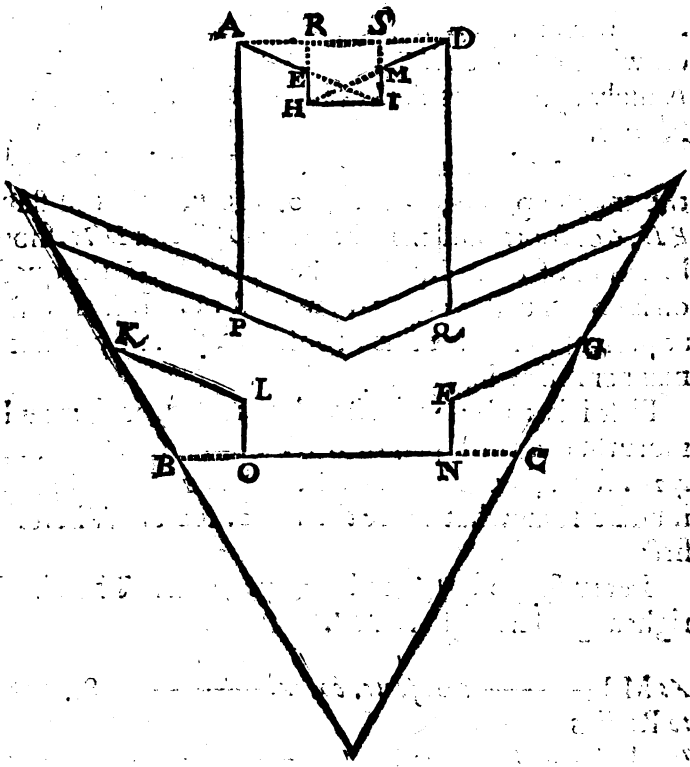
Ravelins thus made against the middle of the curtaine are very frequent in many Forts, being of good use to defend the fronts of the bulworkes; but the other Ravelins or halfe moones opposite to the angular points of every bulworke are not so usuall, notwithstanding, they also are sometimes made, and may be raised and have their Parapets, and ditch as the other, being also flanked by those Ravelins, that are against the curtaines. And without all these is the counterscarpe with a covert way, and an Argin or Parapet, which is inwardly 6. foote high, as hath beene before described, and as by this description, and the Section or Profile thereof may appeare, there is sometimes without the Parapet of the covert way a watred ditch, to impeach any suddaine assault of the enemy. The height, depth and breadth or thickenesse of all these workes are expressed in the sayd Section, wherein the height of the Rampire is 15. foote, and according to the judgement of some should not be more, if the Fort be made in a champion or plaine, where there are no hills neere unto it, but in case there be on any side higher ground that doth command the Fort, then must the Rampire on that side be raised higher, that the Fort may be the better covered and preserved thereby, from the annoyances that may be done against it from that place. And much after the forme here described is *Coverden* in *Friezland* fortified, having 7. bulworkes with Ravelins and halfe moones, &c. as in the figure being the most Royall regular Fort in the Netherlands.

There are also oft times in Forts, Cavaliers, Mounts, Platformes, or batteries, raised higher than any of the foresayd workes, aswell to discover the Country about, as to annoy an enemy; these are sometimes raised upon the bulworkes, if there be roome enough besides to use the flankes, but if the Gorge be too small, they may be raised on the curtaine, a little within the Rampire, so as the walke on the Rampire be not impeached by them.

Of Horne-workes.

BEsides all these, and without all the workes before mentioned, there are sometimes made Horne-workes, yet I have seldome seene of them, but where an enemy is shortly expected. I was at *Breda* in *May An.* 1623. being that Summer wherein it was taken by the *Spaniard*, and then there was (as I remember) five of these Horne-works: others of them I saw at that time at *Bergen-op-som*, which was beseiged the summer before; these are sometimes made against the bulworkes, but more conveniently betweene the bulworkes, and against the curtaine, in forme as followeth.

Let *O N.* be the curtaine of a Fort, *O L.* and *F N.* the flankes *F G.* and *L K.* the fronts, *P Q.* the outside of the ditch, and let the outer foote of the Horne-worke be *P A D Q.* and the distance of the angular points thereof namely *A.* and *D.* from the shoulders of the bulworke *L.* and *F.* be equall to the line of defence *O G.* namely about 72. rods, and let the distance of those angular points *A.* and *D.* be equall to the curtaine of the Fort *O N.* so as the side of the Horneworke *DQ.* may be be in a right line with the flanke *FN.* and *AP.* with *LO.* (some would have the distance of these points *A.* and *D.* and so of *P.* and *Q.* to be lesse than the curtaine by 4 or 5. rods, wherein you may doe as you like best) betweene the angular points *A.* and *D.* are formed as it were two halfe bulworkes, *AEH.* and *DMI.* their fronts being *AE.*



S and

and *D M.* their flankes *E H.* and *M I.* and the curtaine betweene them *H I.* Without this horneworke, that is without the line *P A E H I M D Q.* must be a ditch about 3. rods broad, and 6. foote deepe if the ground be low, otherwise the deeper the better, and within the same line may be a Rampire and Parapet, or onely a Parapet round about 6. foote high and 25. or 30. foote thicke more or lesse as occasion requires; without the ditch I have also seene a covert way and a Parapet thereto. These Horneworkes are sometimes cut off within the face *A E H I M D.* with another like face, namely with fronts, flankes and curtaines parallell to the former.

But now admit in this figure we have the distance of the angular points, *A D.* 420. foote, and the flanke *E H.* 60. foote, and that the fronts *A E.* and *D M.* should be either of them equall to the curtaine *H I.* the question is how much every of them must be. It shall suffice at present to resolve this Probleme by false position in manner following.

First it is to be understood that *H I.* is somewhat more than a third part of *A D.* therefore *A D.* being 420. foote, the third part whereof is 140. the line *H I.* must be somewhat more then 140. feete. Wherefore first

Let us suppose *H I.* to be 147. feete. Then in the right angled triangle *H M I.*

As M I———*60. feete. co. ar.*——— 8,22185.
to Radius
so is H I———147. *feete*——— 2,16732.
to tang. H M I.———67.d. 47'. 47''. ½. 10,38917.

where-

whereto is equall the angle — *S M D*. 67.d. 47'. 47'' $\frac{1}{2}$.

Againe.

As Radius

to M D —— 147 *feete* ———————— 2,16732.

sos. —— *S M D*. 67.d. 47'. 47'' $\frac{1}{2}$. ———— 9,96654.

to —— *S D*. 136. 1. ———————— 2,13386.

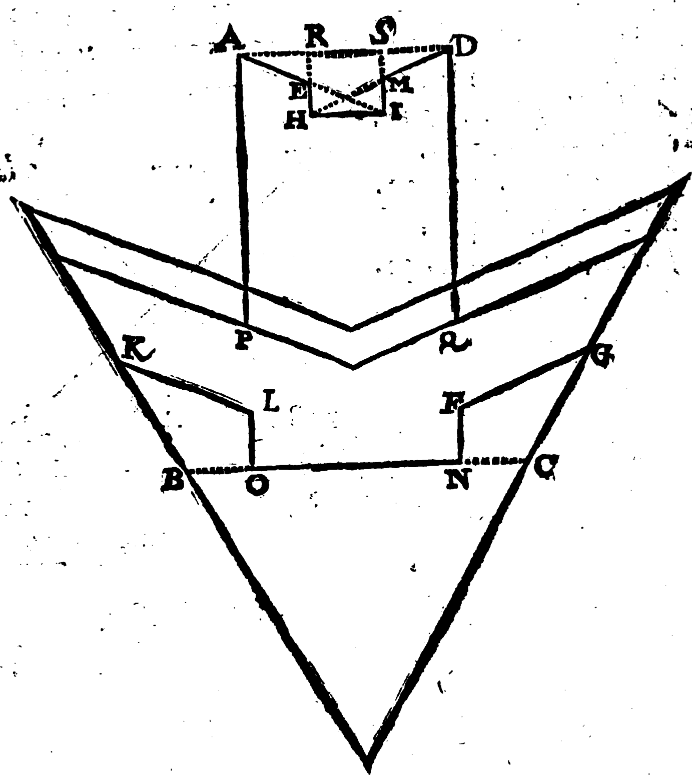
and adding A R. ———— 136. 1.

and R S. ———— 147.

Summe is A D. ———— 419. 2.

which ought to have beene —— 420.

so it is too little by ———— $\frac{8}{10}$.



 There-

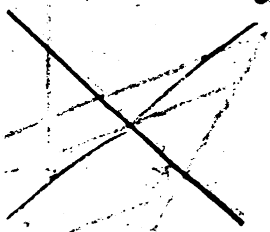
Therefore I suppose againe that *HI.* is 148. and then

As M I ———————— 60. feete. *co. ar.* 8,22185.
to Radius
so is H I. ——————— 148. feete. ——— 2,17026.
to t. H M I. 67. d. 56′. feete.——————— 10,39211.

Whereunto is equall the angle *S M D.* 67. d. 56. *fere.*

As Radius.
to M D. ——— 148. *feete.* ——————————— 2,17026.
so. s. S M D. 67. d. 56′. *fere*———————— 9,96696.
to S D ——— 137. 16. ———————————— 2,13722.
And adding A R. 137.16.
Also — R S. 148.
summe is A D. 422.32.
which should be 420.
so it is + by ——— 2.32.

147 — 0 $\frac{2}{10}$



148 + 2 $\frac{32}{100}$

296	34104
10	100

summe— 37064
100

summe of *er.*— 252
100.

(1 2
1 1 8 8 (0
8 7 0 0 4 } 147 $\frac{120}{272}$ or 147 $\frac{1}{2}$ fere.
2 5 2 2 2
0 5 5
2

Thus having found *H I.* to be 147 $\frac{4}{10}$ we may more easily finde the rest saying,

As M I —— 60. *feete. co. ar.* —————— 8,22185.
to Radius
so is ——— H I. ——— 147.4. ——————— 2,16850.
to tang. H M I. ——— 67. d. 51. ———— 10,39035.

Whereunto is equall the angle *S M D.* 67. deg. 51'. as also the angle *M D Q.*

As Radius
to ——— ——— M D. 147.4. ——— 2,16850.
so. s. c. ——— ——— S M D. s. 22. d. 09. ——— 9,57638.
to ——— ——— M S. — 55. 57. 1,74488.
whereto adding M I. 60.
summe is ——— ——— S I. 115. 57.

As Radius
to ——— ——— M D. 147. 4. ——— 2,16840.
so s. ——— S M D. 67. 51. ——— 9,96670.
to ——— S D. 136. 4. ——— 2,13510.
which doubled is ——— 272. 8.
and adding ——— R S. 147. 4.
summe is ——— 420. 2.

 Which

Which is more by $\frac{1}{10}$ of a foote than it should bee by not taking the foregoing fractions exactly, which you may correct if you please.

CHAP. XII.

Of small Forts or Field Skonces, and marking them out Mechanically, and first of a Skonce of foure sides.

THus have I shewed at large the application of the *Doctrine of Plaine Triangles* by Logarithmes, in this part of *Architecture Military*, which was the onely thing I intended when I began this Treatise. But for the fuller understanding thereof I have (as occasion required) handled other things incident; And now having spent more time herein then at first I assigned for it, and my other occasions calling me away, I might have liberty here to conclude: yet considering that these Forts before mentioned are workes of such labour industry and expence, that they may seeme hard to be accomplished, especially to us, where they are not usuall. I have thought it requisite to shew, some mechanicall and easie way for delineating and setting forth of small Forts or field Skonces: For though it was meete to shew the application in such Royall Forts, as we have before spoken of; yet these being more easily made are more frequent, and have also their necessary uses as well as the former. For it is to be understood that the Fort wherein we have before given an example consisting of 6. bulworkes, is sufficient to containe 600. or

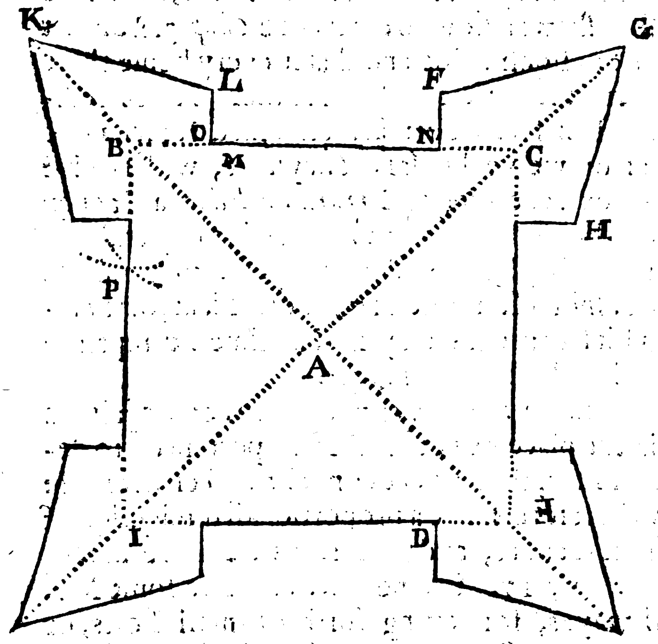
700.

700. houſhoulds more or leſſe, according to the quantity of ground that you aſſigne for each houſe, which we have before ſhewed how to determine *Chap.*3. Admit it containe 600. houſhoulds, and that in every houſe there are two men fit for ſervice, then are there 1200. ſouldiers, which in ſuch a Fort are eſteemed ſufficient to oppoſe ten or twelve thouſand aſſaylants, with twelve Cannons, for (according to *Errard Barleduc*) a Cannon may be diſcharged 80. or 100. times in a day and 12. Cannons, well placed and employed, may ruinate with 1200. ſhot a Rampire of 72 foote thicke, or thereabouts, which breaches may in that time be repaired and maintained by the defendants.

If there be no ſuch force expected to come againſt a Fort, or if the place be not of that importance, to deſerue ſuch a Fort, then it needes not be of ſuch ſtrength: you may therefore make a proportionall diminution of the Gorges, flankes, and fronts, as we have noted, *Chap.*2. *Axiome* 17. But now we come to ſome Mechanicall wayes, for ſetting forth of ſmall Forts, or field Skonces, and ſome ſuch we have before briefely touched, at the end of the ſixth chapter; others I will here ſhew, and firſt begin with a regular Skonce of foure ſides, which are moſt frequent.

Let *B C.* be the ſide of a ſquare to be fortified, and let it be required to ſet out the ſquare and the bulworkes thereof.

Firſt for ſetting out the ſquare, ſet a ſtake at *B.* and alſo at *C.* and having as is aforeſayd a chaine of 5. rods, or 50. feete, meaſure from *B.* towards *C.* 3. rods, which ſuppoſe to end at *M.* and there make a marke; alſo meaſure from *B.* ſquare off, as you gueſſe towards *I.* 4. rods,



rods, and keeping the end at *B*. fixed, turne about that end, or that part of your chaine which is at *P*. that with a sharpe sticke or iron point, you may describe an Arch on the ground; then let one carry the end of your chaine which was fixed at *B*. unto the marke you made at *M*. and measure from *M*. to *P*. the whole length of your chaine 5. rods. marking in what part of the arch before made your chaine doth reach unto which suppose to be at *P*. and there set a stake.

Now suppose the side of your square *BC*. to be 12. rods, then measure also from *B*. to *I*. 12. rods setting a

stake

ſtake at *I.* ſo as theſe three ſtakes *B P I.* may be a right line, and thus you have two ſides of your Fort *B C.* and *B I.* with the right angle at *B.* the like you may doe for the other angles at *I E.* and *C.* and for the ſides *I E.* and *E C.* and ſo the one will examine the other: Or otherwiſe meaſure from the ſtake at *I.* ſquare off, as you gueſſe towards *E.* 12. rods, likewiſe from *C.* towards *E.* 12. rods, and where theſe two meaſures meete in one as at *E.* there drive a ſtake, and ſo is the ſquare ſet out.

Now for the center of this ſquare, let one man ſtand at *B.* and another at *C.* and let a third man drive a ſtake ſo at *A.* that the man at *B.* may ſee it, in a right line towards *E.* and the man at *C.* may ſee it in a right line towards *I.* and ſo is the ſtake at *A.* the center or middle of the Fort.

Next for the bulworkes, divide the ſide of thē ſquarē *B C.* into 5. equall parts, and make the Gorge lines *B O.* and *N C.* either of them one of thoſe parts, and ſo all the other Gorge-lines, alſo make the head line *B K.* as much as two of thoſe parts, driving a ſtake at *K.* ſo as you may thence ſee the ſtake at *B.* and that at *A.* or *E.* all in a ſtreight line, the like doe for the angular points of the other three bulworkes. Then divide the Curtaine *O N.* into foure equall parts, and make the flanke *O L.* and ſo *N F.* and all the other flankes, to be one of thoſe parts; but for ſetting thoſe flankes ſquare off from the curtaines, you may drive a ſtake, ſo at the ſhoulder *F.* that you may ſee from thence the ſtakes at *N.* and *D.* all three in a right line, and the like is to be underſtood of all thē other flankes. And thus are the curtaines, together with the flankes and fronts of the bulworkes ſet out.

Now supposing the side of the square *B C.* to be 12. rods or 120. feete, then is the Gorgeline *N C.* 24. feete, the head-line *C G.* 48. feete, the curtaine *O N.* 72. feete, and the flanke *F N.* being a fourth part of the curtaine is 18 feete.

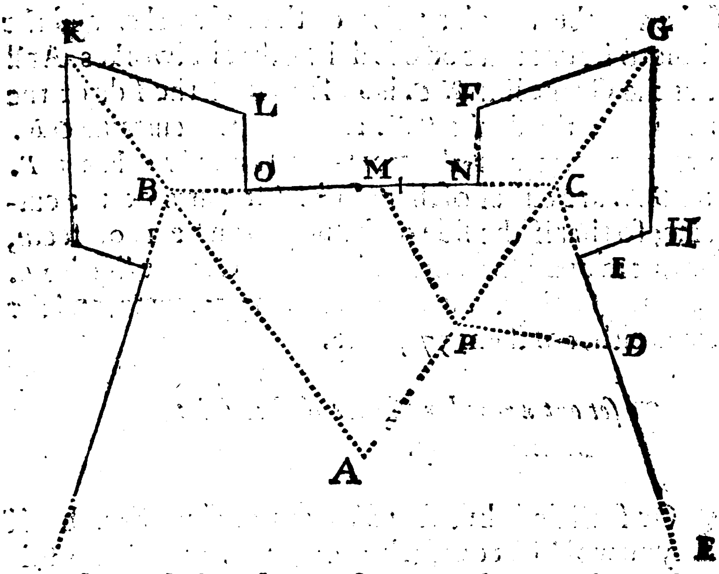
Otherwise having set out as before, the curtaines and Gorge-lines, and the angular points of the bulworkes, as *K.* and *G.* and stakes being set at the ends of every curtaine, as at *O.* let one drive a stake at *F.* so as one standing at *G.* may see it to bee in a right line with the stake at *O.* and he that stands at *F.* may see it to be in a streight line with the stake *N.* and *D.* so shall the stake at *F.* be the shoulder of that bulworke, and in like sort may all the other shoulders of the bulworkes be set out, and consequently all the flankes and fronts.

And thus having described at large, the staking out of these Skonces of foure sides, which are most usuall, we shall be briefer in the rest that follow.

To set out Mechanically a Regular Skonce of five sides.

LEt *B C.* be one side of a Pentagon, first then to set out the other sides Mechanically; having set a stake at *B.* and another at *C.* measure from *C.* towards *B.* 53. feete, wanting a tenth part of a foote, that is from *C.* to *M.* then measure from *M.* 45. feete towards *P.* also from *C.* 45. feete towards *P.* and where these two measures concurre namely at *P.* make a marke or drive a stake, then measure from *P.* to *D.* 45. feete, and from *C.* to *D.* 53, feete, lacking $\frac{1}{10}$ part of a foote, and where these two measures concurre as at *D.* there set a

stake

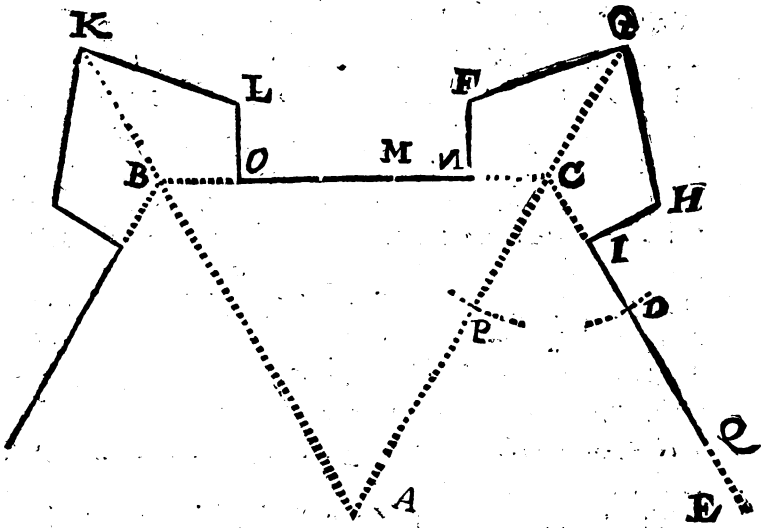


ſtake, meaſuring forwards towards *E*. till you have made *C E*. equall to *C B*. and that ſtanding at *E*. you may ſee the ſtakes *C*. and *D*. in a right line with your eye, then drive a ſtake at *E*. and in like ſort proceeding you may ſtake out the other three ſides.

Then for the bulworkes, divide one of the ſides as *B C*. into five equall parts, and make the Gorge-lines as *N C*. and *C I*. to be either of them one of thoſe parts. Likewiſe let the flankes *N F*. and *I H*. be either of them one of thoſe parts, which flankes may be ſet ſquare or perpendicular to the ſides, which they flanke by the meaſures, 3. 4. 5. as we have before ſhewed. Laſtly divide one of the curtaines, as *O N*. into 5. equall parts, and meaſure from *F*. towards *G*. ſo much as 4. of thoſe parts come to, alſo from *H*. towards *G*. aſmuch, and where thoſe meaſures meete, as at *G*. there drive a stake for the angular point of the bulworke, and the like is to be understood of all the other bulworkes. And thus the Gorge line *N C.* is a fift part of the side of the pentagon; the flanke *F N.* as much, the curtaine *O N.* three fift parts, and the fronts of the bulworkes *G F.* and *G H.* are either of them foure fift parts of the curtaine; so that if the side of the pentagon be 120. feete, (as so it may be, or more or lesse) the George line is 24. feete, the flanke as much, the curtaine 72. feete, and the fronts either of them 57 $\frac{3}{5}$ feete.

To set out a regular Skonce of sixe sides Mechanically.

YOu shall finde but few Skonces of sixe sides, but if you would set out such an one, you may doe as followeth. Let *B C.* be the side of the Hexagon. First then for setting out the other sides, divide the side *B C.* into five equall parts, take with your chaine two of those parts, as from *C* to *M.* and with that length of your chaine strike an arch towards *A.* namely at *P.* then let one carry the end of the chaine from *C.* to *M.* and keeping it still at the same length as before, note where it intersects the foresayd arch which will be at *P.* there drive a stake. Also keeping still the same length of your chaine, let one remove the end from *M.* to *C.* againe, and strike the arch at *D.* then remove from *C.* to *P.* striking on the ground the arch at *D.* keeping it still at the same length as before, note how farre it reacheth in the arch before described at *D.* which will be to the point *D.* where drive a stake, and measure so from *C.* towards *E.* that the side *C E.* may



may bē equall to *C B*. and that these 3. markes *C D E*. bē in one right line, and so you have two sides of the Fort intended, namely the side *B C*. at the first given, and the side *C E*. thus last set out, and in like sort you may set out all the other sides.

The same sides might also have beene otherwise set out, by making *B A*. and *C A*. either of them equall to *B C*. (in this example onely) and so their concourse at *A*. is the center of the Fort. Also measure the same distance from *A* to *E*. and from *C*. to *E*. so that these 3 lines, *C A*. *A E*. and *C E*. may be equall, the concourse or meeting at *E*. is another corner, and the streight line from *C*. to *E*. is another side, and in like sort may all the sides be set out.

Then for the bulworks. Whereas the side *B C*. is before divided into five equall parts; let the Gorge lines

N C. and *C I.* be either of them one of thoſe parts, alſo let the flankes *N F.* and *I H.* be either of them one of thoſe parts and perpendicular to the ſides which they flanke. For ſetting them out perpendicular you may doe it ſeverall wayes, namely either by thoſe meaſures 3. 4. and 5. as we have before ſhewed in ſetting out the ſides of a ſquare, or having ſtaked out the points round about, and then parted the curtaines and Gorge-lines as *O N I Q.* &c. the oppoſite ſtakes will direct you to goe ſquare off, as we have before ſhewed in ſetting out the flankes of a foure ſided Fort: Or laſtly the ſtake at the point *P.* may direct you, foraſmuch as thoſe three points *P N F.* or *P I H.* are in a right line, and the like is to be underſtood of the reſt.

Then for the Fronts, (one of the ſides as *B C.* being as aforeſayd divided into five parts) meaſure from *C.* towards *G.* two of thoſe parts for the head-line, and at the end of that meaſure drive a ſtake, ſo as you may ſee it in a right line with the ſtakes at *C.* and *P.* or *A.* and ſo is one of the bulworkes ſtaked out, and in like ſort you may ſtake out all the reſt.

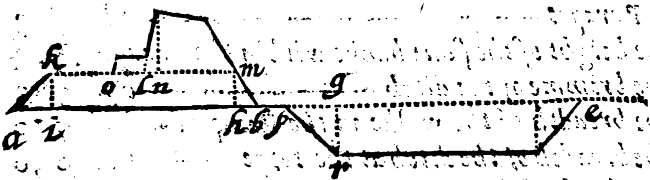
And thus the Gorgeline *N C.* is a fift part of the ſide of the hexagon *B C.* and ſo alſo is the flanke *N F.* the curtaine *O N.* is three fift parts, and the head-line *C G.* is two fift parts, or two ſuch parts as the curtaine is three, ſo that if the ſide of the Hexagon *B C.* be 20. rods, or 200. feete, the Gorge-lines are every of them 4. rods, and the flankes as much, the Curtaines 12. rods, and the head-lines every of them 8. rods. But (as in this example) if the ſide *B C.* be but 120. feete, then the Gorge-lines are every of them 24. feete, the

flankes

flankes asmuch, the Curtaines 72. feete, and the head-lines 48. feete.

The Section or Profile of these Skonces.

THe height, breadth, and scarpings, of the Rampire, Parapet, Ditch, &c. of these Skonces, are represented in this Section. Thus *a b.* represents the breadth or thickenesse of the Rampire at the foote, which may be 24. 30. or 40. feete, the height thereof



i k. 4. 6. or 8. feete, and the inward Scarpe *a i.* asmuch, the outward Scarpe *h b.* 2. 3. or 4. feete, the breadth of the Parapet at the foote *l m.* 8. 10. or 12. feete, the brim of the ditch *b p.* may be three feete, or sometimes nothing at all. And so the rest of the measures such as by this ensuing table appeareth, wherein I have followed a late *Dutch* writer.

The

		Feete.	
The breadth of the Rampire at the foote —— a b.	24	32	40
The outward Scarpe of the Rampire —— h b.	2	3	4
The height of the Rampire —— —— i k.	4	6	8
The inward scarpe —— —— —— a i.	4	6	8
The breadth of the Parapet at the foote —— l m.	8	10	12
The inward Scarpe of the Parapet —— —— l n.	1	1	1
The height of the Parapet on the outside ——	4	4	4
The height of the Parapet inwardly —— ——	6	6	6
The thickenesse of the Parapet at the toppe ——	5	7	9
The breadth of the banke or footepace of the Parapet —— —— —— —— —— o l.	3	3	3
The height of the same banke within the Parapet	1 ½	1 ½	1 ½
The brimme of the ditch —— —— —— b p.	3	3	3
The breadth of the walke on the Rampire — k o.	7	10	13
The breadth of the ditch at the toppe —— p e.	30	36	54
The depth of the ditch —— —— —— g r.	6	6	8
The Scarpe of the ditch —— —— —— p g.	6	6	8
The breadth of the ditch at the bottome —— ——	18	24	38

In these I have expressed no Covert way without the ditch, which notwithstanding you may make if you please, and if the ditch be not full of water, you may take away the edge thereof at *e* 1 ½. foote deepe, and about 3. or 4. foote broad round about, then leaving 4. or 5. foote breadth further out, you may there raise the Parapet of the Covert way, 4. or 4 ½. foote high.

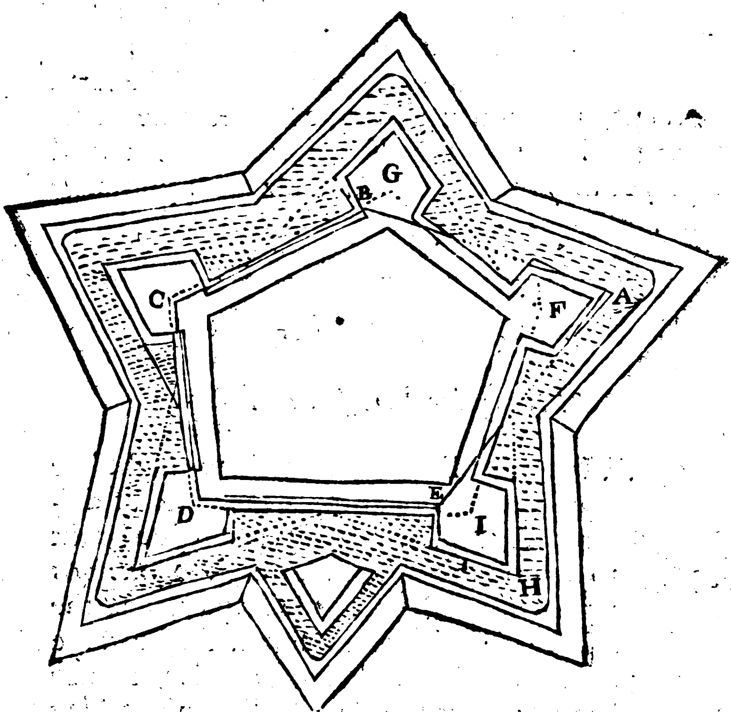
In raysing the Rampire, at the foote thereof on the outside

outside you may plant young Willowes, Haw-thorne bushes, and other such like, and bring up the face of the Rampire with turfes, and when the Rampire is one foote high, it must be beaten and stamped downe till it come to 8. or 9. inches, that it may settle no more, and when the face is raysed five rankes of turfe, you may plant other young Willowes or bushes, (especially if the earth be sandy) and sow Oates and Hay seed chiefely such seede as hath a strong spreading roote, betweene every ranke of turfes, that the rootes may knit and fasten the turfes together. And so if the face be of platt-worke, that is of earth beaten with batts, you may sow it with such grasse and hearbes as are apt to spread and cover the face of the worke, and moysten the earth in platting it, that it may grow the better. The Parapet being raised upon the Rampire almost to its full height, you may then make your Palizado if you make any, &c.

CHAP. XIII.

Of Irregular Fortification.

OF Irregular Fortifications there might bee proposed, almost an infinite number of different examples. But in generall you ought to observe so neere as may be, the *Axiomes* set downe in the second Chapter, and the examples we have given in regular Forts. And first the figure proposed to be fortified being irregular, reduce it to as much regularity as the place will admit, taking in and leaving out here and there a little, to make some neere equality of the sides and angles. Then if any angle of your figure be lesse than 90. degrees, you are not to set a bulworke on that angle, but rather to make that angle, to be the flanked angle of a bulworke, diminishing it somewhat if occasion require. And for the other angles of your irregular figure, you are to fit bulworkes so, as the flanked angle of the bulworke may be answerable to the angle of the Poligon whereon it stands, according to either of the two rules before gi-



ven

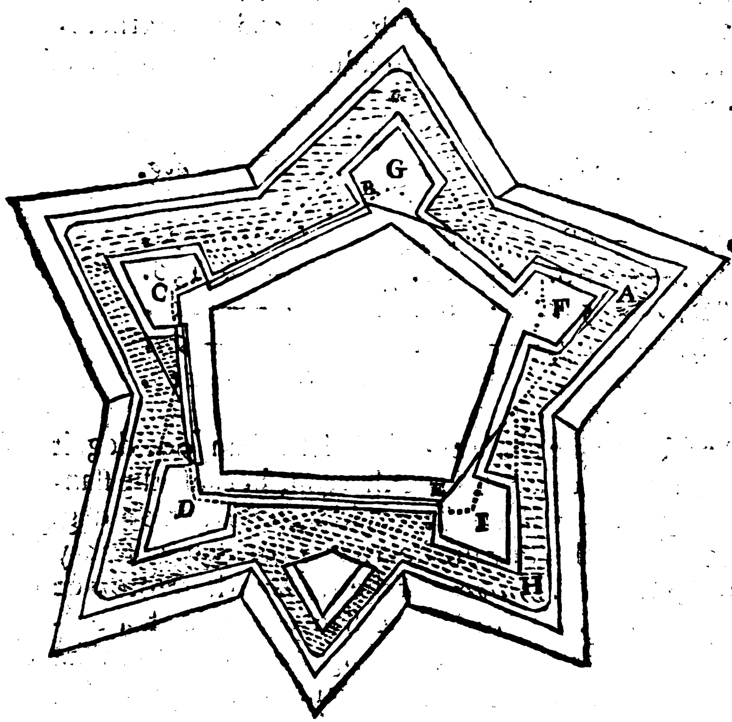
ven *Chap.* 4. That is first, unto halfe the angle of the poligon figure, adde 15. deg. the summe is the flanked angle of the bulworke: Or otherwise take two third parts of the angle of the poligon, for the flanked angle of the bulworke to be thereon placed; Yet is ⅔ of that angle to be more than 90. d. but it may suffice to make the angle of the bulworke onely 90. d. Take this example which I have here set downe almost in the same manner as is done by *Sa. Marolois* in his booke of Fortification.

Let *A B C D E.* be an irregular pentagon to be fortified with such bulworkes as may be suteable to the angles of the figure. First then the sides and angles thereof are to be measured, which admit we finde to be as followeth.

	rods.	*feet.*		*deg.*
AB.	68.	04.	*A*	72.
BC.	60.	00.	*B*	136.
CD.	55.	02.	*C*	111.
DE.	67.	02.	*D*	97.
			E	124.

And seeing the angle at *A.* is lesse than 90. deg. it is not fit to place a bulworke thereon, because the flanked angle of that bulworke would be lesse than 60. deg. and the angle flanking greater than 150. deg. contrary to the 9. and 11. *Axiomes* of the 2. *Chap.* therefore wee make that angle *A.* to be the flanked angle of a bulworke, and the angle of the poligon to be *F.* so as the right lines *F G.* and *F I.* intersect the lines *B C.* and *C E.*

in the points *G.* and *I.* upon which angles, and according to the proportion of the sides we describe the bulworkes, alwayes observing that the angle of the polligon sheweth of what kinde the bulworke thereon set must be, whether of a Pentagon square or Hexagon: proportionating the parts of the bulworke, according to the lesser of the two sides, and so will that figure be fortified as here appeareth. And because the side *D E.* being drawne forth to *I.* is longer then the rules and proportions before set downe in regular figures will ad-



mit

mit of, it will be necessary betweene the two bulworkes *D.* and *E.* to make a Ravelin, as here appeareth; such that the fronts thereof may be scowred and defended from the flankes and fronts of those two bulworkes, and so that angle will be more or lesse, according to the length or shortnesse of the curtaine, and the fronts of this Ravelin may be either of them 22. or 24. rods, or something more or lesse, as the place and scituation shall require. And for your better understanding of mine intention, in the fortification of places irregular such whose angles are not lesse than 90. deg. which is the angle of a square, and their sides not much different from those of regular figures; you may doe thus.

Let it be required to Fortifie the angle *C.* being an angle of 111. deg. which is neere unto the angle of a pentagon. According to which take the shortest of the two sides, *BC.* and *CD.* which is here *CD.* containing 55. rods, or 552. feete, searching also in the foregoing Table of the demensions of regular Fortifications, for the demiensions appertaining to a Pentagon, and then say by the rule of proportion

As the side of a Pentagon being ——	66.36.	6,17810.
hath to the front of the bulworke ——	28.00.	3,44716.
so the side of a Pentagon being ——	55.02.	3,74052.
may have the front ——————	22.30.	3,36578.

And thus we finde the front for such a bulworke to be 23. rods, 2. feete, and two tenths of a foote, so according to this example you may in like manner finde by the rule of proportion, the flanke and Gorge-line, and so all the lines and angles in this bulworke *C.* as alſo the other parts of this whole Fort. Holding it alwayes for a certaine rule that the angles of a Poligon to be fortified muſt be at the leaſt right angles, and if there be any angle leſſe than a right angle, you may make that the flanked angle of a bulworke, inlarging or leſſening it ſomewhat, if occaſion require, till it become a competent angle for ſuch a bulworke. And if the ſides of the poligon propoſed, doe exceede the ſides of the inward Poligons, ſpecified in the foreſayd Tables, we may make them as ſides of the outward Poligons, and trace out the Fort within them, and that according to the ſpecies of every ſeverall angle *F G C D I*, and ſo ſhall the figure propoſed be fortified.

If you deſire more examples touching the Fortification of places irregular, you may peruſe *Sam. Marolois* his booke of Fortification, thus much at preſent may ſuffice.

FINIS.

ERRATA.

PAge 3. line 24. for Coverat reade Covert. p. 11. l. 3. for C. r. D. l. 17. r. 6,0418290. p. 29. l. 5. r. 7,71541. p. 36. l. 10. for R r. O. p. 44. l. 15. for C. r. H. p. 67. l. 4. for NON r. NOW. p. 95. l. 4. r. face. p. 100. l. 2. for n. r. D.