

# Archaic cuneiform numbers

Robin Leroy, Anshuman Pandey, and Steve Tinney

2024-09-08

## Contents

<b>1</b>	<b>Summary</b>	<b>2</b>
<b>2</b>	<b>Proposed changes to the Standard</b>	<b>3</b>
2.1	Summary of proposed characters . . . . .	3
2.2	Properties . . . . .	3
2.3	Character names list . . . . .	3
2.4	Core specification text . . . . .	3
<b>3</b>	<b>Rationale for curviform–cuneiform disunification</b>	<b>4</b>
3.1	The cuneiform encoding model . . . . .	4
3.2	Arguments for curviform–cuneiform unification . . . . .	5
3.3	A primer on classic Ur III and Old Babylonian metrologies . . . . .	7
3.3.1	The discrete counting system . . . . .	7
3.3.2	The area system . . . . .	7
3.3.3	The capacity system . . . . .	8
3.3.4	The length system . . . . .	9
3.3.5	Fractions . . . . .	10
3.4	Curviform numerals in early metrologies . . . . .	10
3.4.1	Field lengths in Nirsu . . . . .	11
3.4.2	Dyke lengths in Nirsu . . . . .	12
3.4.3	Butter, cheese and wheat in Nirsu . . . . .	12
3.4.4	Grain in Ebla . . . . .	13
3.4.5	Use in modern publications . . . . .	14
3.5	Non-numeric usage . . . . .	21
3.6	The limited benefits of diachronic encoding for numerals . . . . .	21
3.7	Compatibility considerations . . . . .	23
3.7.1	The case of ŠAR <sub>2</sub> . . . . .	23
3.7.2	Transliteration . . . . .	24
3.8	Conclusions . . . . .	25
<b>4</b>	<b>Rationale for ED–Uruk numeral unification</b>	<b>26</b>
<b>5</b>	<b>Considerations on individual numeral series</b>	<b>27</b>

<b>6 Characters not included in this proposal</b>	<b>27</b>
6.1 Missing numerals	27
6.2 Stacking patterns	28
6.3 Other glyph variants not reflected in transliteration	29
<b>Acknowledgements</b>	<b>29</b>
<b>References</b>	<b>30</b>
Artefacts	30
Unicode documents	36
Online corpora and related projects	37
Other documents	37

## 1 Summary

This document proposes encoding some numerals used in the fourth millennium (Uruk IV and Uruk III) and Early Dynastic period in conjunction with the Sumero-Akkadian cuneiform script<sup>1</sup> and the proto-cuneiform script<sup>2</sup>. The proposed characters are listed in §2. Most of them were listed in [L2/23-190]. The present document provides a more detailed rationale for their encoding and additional information about their identity. Some characters have been removed, in some cases because they are non-encodable variants, in others because their encodability should be considered as part of the proto-cuneiform proposal; these are discussed in §??. The glyphs have also been reworked, and additional characters used in the Early Dynastic period have been added.

The non-numeric signs of proto-cuneiform will be the subject of a separate proposal; we need only note here that the divergence between the approaches to character identity in modern scholarship requires that proto-cuneiform be disunified from cuneiform: proto-cuneiform is effectively treated as an undeciphered script. In contrast, the cuneiform encoding model is semantic, requiring an understanding of the text to correctly encode it.

However, the *numerals* used in proto-cuneiform should be unified with ones used in the Early Dynastic period, for the reasons set forth in §4. The proposed “curved”, or “curviform”, numerals<sup>3</sup> should however *not* be unified with the already-encoded cuneiform numerals<sup>4</sup>. Since the encoding proposals for the cuneiform script twenty years ago provisionally considered the curviform numerals to be glyph variants of the cuneiform numerals, a detailed rationale is provided in §3, including compatibility considerations in §3.7.

<sup>1</sup>ISO 15924: Xsux, Script property value long name: Cuneiform; encoded since Unicode Version 5.0.

<sup>2</sup>ISO 15924: Pcun, not yet encoded.

<sup>3</sup>Impressed into clay using cylindrical styli, held either perpendicular to the tablet, yielding • (small stylus) or ● (large stylus), or at a shallower angle: ◐, ◑ (small stylus), ◒ (large stylus). Some numerals are composed of multiple such impressions, e.g., ◓. The terms “curved”, “curviform”, “curvilinear”, and “round” can be found in the literature. We avoid the term “round” here as it has other meanings in the context of numbers. We use “curviform” in this document as, being the least common term, it is least likely to lead to confusion, and “CURVED” in the character names for consistency with documentation about the modifier @c used in machine readable ATF transliterations [inlineATF].

<sup>4</sup>Impressed into clay using a stylus with a trihedral end: — (stylus held horizontally), † (vertically), ↘ (diagonally) ‹ (with the head of the stylus), ‡ (stylus pressed deeper, forming a larger wedge), ‡ (combining † and ‹), etc.

The overall picture of unifications and disunifications over time is illustrated in table 1. The Script\_Extensions property assignments in §2.2 reflect the overlap. Many of these numerals are also used in proto-Elamite<sup>5</sup> texts, where they are treated as identical characters in scholarship on proto-Elamite, so that they should be unified with the ones proposed in [L2/23-196]. However, in the interest of time, we do not provide a detailed rationale for this unification in this document, and we are not proposing that the numerals be given the corresponding Script\_Extensions property value for now. Neither do we propose encoding any numerals that are solely attested in proto-Elamite texts, or well-attested in proto-Elamite texts but insufficiently attested in Uruk.

[TODO(egg): Mention the other sections here too.]

	Uruk III & earlier	ED – Ur III	OB & later
Numerals	This proposal		
Non-numeric signs	Future Pcup	Existing Xsux	

Table 1: Usage of existing, proposed, and future characters across functions and time periods.

## 2 Proposed changes to the Standard

### 2.1 Summary of proposed characters

### 2.2 Properties

### 2.3 Character names list

### 2.4 Core specification text

Amend [Uni16, §11.1.2, sub “Cuneiform Numerals”], as follows:

**Cuneiform Numerals.** In general, numerals that also have a phonetic, logographic, or determinative value are encoded in the main Cuneiform block; as a result, some series of numerals, such as 𐎶–𐎶𐎶 1(diš)–9(diš) or 𐎶–𐎶𐎶 1(u)–9(u), are split across the two blocks. Numerals have been encoded separately from signs that are visually identical but ~~semantically different~~ etymologically unrelated (for example, U+1244F 𐎶 CUNEIFORM NUMERIC SIGN ONE BAN2, U+12450 𐎶 CUNEIFORM NUMERIC SIGN TWO BAN2, and so on, versus U+12226 𐎶 CUNEIFORM SIGN MASH, U+1227A 𐎶 CUNEIFORM SIGN PA, and so on).

The relation between series of numerals depends on the metrological system; for instance, when counting talents, written 𐎶𐎶 (a unit of weight, approximately 30 kg), 𐎶𐎶 is used for “one talent”, and 𐎶𐎶𐎶 for “ten talents”. However, when measuring areas, the area 𐎶𐎶 (one *būrum*) is eighteen times 𐎶𐎶 (one *ikūm*, approximately 3600 m<sup>2</sup>). The Numeric\_Value property assignment of a cuneiform numeral therefore

<sup>5</sup>ISO 15924: Pelm, not yet encoded.

reflects only its relation to the first numeral in its series, rather than the absolute numeric value that it might represent. For instance, the number “fifty” is written 𐎶𐎵, but U+12410 𐎶 CUNEIFORM NUMERIC SIGN FIVE U has Numeric\_Value=5, as it is  $5 \times 𐎵$ .

In the third millennium, and especially in the Early Dynastic period, some numerals are written using a cylindrical tool, rather than the cuneiform stylus, forming curved rather than cuneiform numerals (𐎶 rather than 𐎵). The cuneiform numerals are descended from these curved numerals. However, in the Early Dynastic period, the curved numerals contrast with the cuneiform ones, and are used together with them in several metrological systems; they are therefore separately encoded. Most curved numerals are encoded in the Archaic Cuneiform Numerals block, with the exception of two fractions in the Cuneiform Numbers and Punctuation block: U+1245D 𐎶 CUNEIFORM NUMERIC SIGN ONE THIRD VARIANT FORM A and U+1245E 𐎶 CUNEIFORM NUMERIC SIGN TWO THIRDS VARIANT FORM A, the curved counterparts of U+1245A 𐎶 CUNEIFORM NUMERIC SIGN ONE THIRD DISH and U+1245B 𐎶 CUNEIFORM NUMERIC SIGN TWO THIRDS DISH.

Add after [Uni16, §11.1.3]:

#### **11.1.4 Archaic Cuneiform Numerals: U+12550–U+TODO**

TODO something about consistent size

*The sign ŠAR<sub>2</sub>.*

Amend [Uni16, §24.1.2, sub “Dashed Box Convention”], third paragraph, as follows:




In a few cases of very wide **punctuation** characters that do not naturally fit into a code chart cell, the representative glyph may be shown with an artificially narrow shape, displayed inside the dashed box, with or without additional annotation, to indicate this adjustment of shape.

## **3 Rationale for curviform–cuneiform disunification**

The numbering systems that use cuneiform numerals are descended from the ones that use curviform numerals, and many of the cuneiform signs have clear curviform counterparts across this transition. Co-occurrences are sometimes described by analogy to distinctions that are not the realm of plain text, as in [Pow72, p. 215] “in the same fashion as we use black and red ink”; however, we must bear in mind that such analogies are not made in the context of character encoding discussions. In 2004, the curviform numerals were deemed unencodable for the time being; however, closer inspection reveals that the distinction functions less like markup than was argued at the time, and that the unification is problematic.

### **3.1 The cuneiform encoding model**

As outlined in, e.g., [UTR56], the cuneiform encoding model is diachronic; each character may have wildly different glyphs depending on time period and region. For instance, the sign IM may resemble 𐎶 in texts from Early Dynastic IIIa Šuruppag


















as in the character code charts,  later in the third millennium<sup>6</sup>,  in Old Babylonian cursive,  in Neo-Assyrian, but is always encoded as U+1214E CUNEIFORM SIGN IM.

This encoding model allows for the interoperable representation of editions of diachronic reference works such as sign lists<sup>7</sup> and dictionaries<sup>8</sup>, and of composite texts<sup>9</sup>. By being compatible with similarly diachronic transliteration practice, *i.e.*, by avoiding distinctions finer than those made in transliteration, the encoding model also allows for automated conversion of transliterated corpora to cuneiform, which has proven useful as a processing step in analyses such as [Rom24; JJ24]<sup>10</sup>. The diachronic approach is also useful for pedagogic applications<sup>11</sup>.

### 3.2 Arguments for curviform–cuneiform unification

In this context, the argument was made in [L2/04-099], as part of discussion of the cuneiform encoding<sup>12</sup> that the curviform numerals, which occasionally appear in the Ur III period and are used heavily in the Early Dynastic period, were a stylistic distinction unifiable with the cuneiform digits, and that an archaizing Ur III font or an Early Dynastic font could have curviform glyphs for the appropriate characters.






















Some co-occurrence of curviform and cuneiform digits was known and acknowledged. [L2/04-099, p. 3] cites [NDE93, p. 62], which is a copy of [P020054], an Early Dynastic IIIb administrative tablet from Nirsu. The excerpt cited, lines 1–3 of column 1 of the obverse, is as follows:

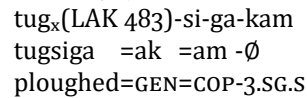
 <sup>13</sup>						
1(ηeš <sub>2</sub> )	1(u)	1/2(diš)	5(diš <i>tenû</i> )	gi	us <sub>2</sub>	sa <sub>2</sub>
	7.5 (ropes)		5	reed	side	equal
 <sup>14</sup>						
3(u)	6(diš <i>tenû</i> )	gi	sa <sub>2</sub>	sa <sub>2</sub>		
3 (ropes)	6	reed	front	equal		
						
ašag-bi	1(bur <sub>3</sub> <sup>c</sup> )	1(eše <sub>3</sub> <sup>c</sup> )	1(iku <sup>c</sup> )	1/2(iku <sup>c</sup> )		
ašag=bi						
field=DEM <sup>15</sup>						

<sup>6</sup>Merging with U+1224E CUNEIFORM SIGN NI2.

<sup>7</sup>Notably [OSL] and the online edition of [Bor10] in [eBL, Signs].

<sup>8</sup>Notably [ePSD2] and the online edition of [Sch10] in [eBL, Dictionary].

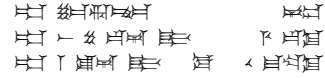
<sup>9</sup>For example, there are Neo-Assyrian and Neo-Babylonian copies parts of the laws of                       



465 metres, equal lengths  
198 metres, equal widths  
this field is 9, 8 hectares of ploughed land

- the functions and use of the numerals vary beyond the mere  $\triangleright/\nabla$  switch;
- the contrast between curviform and cuneiform numerals is commonly used to distinguish metrological systems;
- some metrological systems commonly mix curviform and cuneiform in single numerical expressions.

### 3.3 A primer on classic Ur III and Old Babylonian metrologies


  
 I want to write tablets: the tablet of  
 1 cor of barley to 600 cor; the tablet  
 of 1 shekel of silver to 10 minas [...]  
 Edubba'a D

Before diving into the usage of the curviform numerals in the Early Dynastic period to explain the constrast with cuneiform numerals, it is useful to understand the usage of the already-encoded characters in the Ur III and Old Babylonian periods.

As is well known<sup>18</sup> a sexagesimal place value system (SPVS) was used in Mesopotamia from the late third millennium onwards. One should bear in mind, however, that other systems were used; the SPVS was primarily used in calculations, with results being expressed in non-positional systems [Rob08, p. 76; Rob22]. The digits 1–59 of the SPVS have inner structure which is reflected in the encoding: the digits 1–9 are the individual characters  $\text{I}$ – $\text{IX}$ , the multiples of ten (10–50) are  $\text{X}$ – $\text{XL}$ , but the other digits 11–59 are sequences  $\text{X}$ – $\text{IX}$   $\text{I}$ – $\text{IX}$ ; in effect the base-sixty digits are themselves written in base ten, with a different set of symbols for the tens place. This reflects the origin of the sexagesimal place value system; it derives from a *non-positional* system, hereafter the *cuneiform discrete counting system*  $S_{\text{Ur III/OB}}$ , which had different signs for the units  $\text{I}$ – $\text{IX}$ , tens  $\text{X}$ – $\text{XL}$ , sixties  $\text{I}$ – $\text{IX}$  (with larger wedges than the units), multiples of six hundred  $\text{K}$ – $\text{KL}$ , multiples of three thousand six hundreds  $\text{D}$ – $\text{DL}$ , and multiples of thirty-six thousand  $\text{D}$ – $\text{DL}$ .

#### 3.3.1 The discrete counting system

The relations between the values of the signs in the cuneiform discrete counting system may be summarized by the following factor diagram<sup>19</sup>, where the number over arrow indicates the multiple of the preceding sign (right of the arrow) corresponding to the following sign (left).

$$\text{D} \xleftarrow{10} \text{D} \xleftarrow{6} \text{K} \xleftarrow{10} \text{I} \xleftarrow{6} \text{X} \xleftarrow{10} \text{I} \quad (S_{\text{Ur III/OB}})$$

For example, the number  $1729 = ((2 \times 10 + 8) \times 6 + 4) \times 10 + 9 = 28 \times 60 + 49$  would be written  $\text{K} \text{X} \text{X} \text{I} \text{X}$  in the discrete counting system, and  $\text{X} \text{X} \text{X} \text{X} \text{X}$  in the sexagesimal place value system.

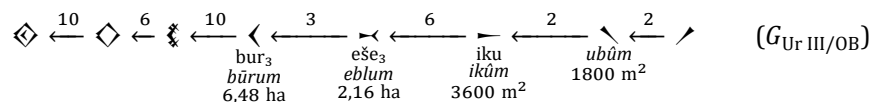
#### 3.3.2 The area system





























The discrete counting system was not the only non-positional system in use in the Ur III and Old Babylonian periods; different systems were in use depending on what was being counted or measured. For instance, field areas were measured using the following system, where for the named units we have provided the name of the unit in transliterated Sumerian, normalized Old Babylonian Akkadian, and

<sup>18</sup>See, e.g., [Uni16, §22.3.3, sub “Cuneiform Numerals”].

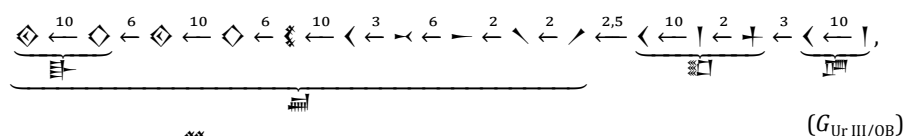
<sup>19</sup>These diagrams, which have become standard in discussions of Mesopotamian metrology, originate with [Fri78, p. 10], where they are called *step-diagrams*, see Figure 3.


the approximate metric equivalent [Fri07, p. 378; Rob19]:



Note that for the range of areas given above, this system does not use any symbols separate from the numerals for the individual units (*ubûm*, *ikûm*, *eblum*, and *bûrum*). As mentioned in [Rob19], the whole numeric expression for the area would be followed by the sign  functioning as punctuation<sup>20</sup>, but the numerals are tied to the metrology; thus a surface of 5 *bûr* 1 *ebel* 4 *ikû* (100 *ikû*, 36 ha) would be written<sup>21</sup>                              

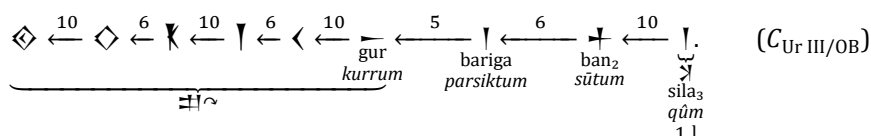
For areas smaller than a quarter *ikūm*, an overt unit is used, with one  $\text{𐤀𐤍}$  (*sar*, *mūšarum*), approximately 36 m<sup>2</sup>, written  $\text{𐤀𐤍𐤁𐤏}$ , equal to one hundredth of an *ikūm*, then sexagesimally subdivided in 60  $\text{𐤁𐤏}$  (*gin<sub>4</sub>*, *šiqlum*, “shekel”). For areas greater than 3600 *būr*, the  $\text{𐤁𐤏}$  and  $\text{𐤁𐤏𐤁𐤏}$  numerals are reused with a suffix  $\text{𐤂𐤏}$  (*gal*, “big”), as follows [Robo8, p. 295 nn. b, c; Fri07, p. 378; Rob19]:



e.g.,  for  $(2 \times 3600 + 20 \times 60 + 49) \text{ bur}$   
 $5 \text{ ik} \dot{u} (5 + \frac{1}{2}) \text{ m} \dot{u} \text{ sar } 19 \text{ ši} \text{qil}$ . Factor diagrams in this document will use bottom curly brackets in this fashion to separate numerals from units and other suffixes.

### 3.3.3 The capacity system

Another such system of note is the one for capacities<sup>23</sup> [Fri07, p. 376; Rob19],



In the above diagram, the numerals for  $\text{ban}_2$  are 𐤁, 𐤂, 𐤃, 𐤄, and 𐤅, and those for  $\text{bariga}$  are 𐤆, 𐤇, 𐤈, and 𐤉 (contrast ordinary 𐤈 and 𐤉 otherwise used with 𐤆 numerals). Further, we have used the symbol  $\sim$  to express that, as described in [Hue11, p. 585 nn. (b), (f)], the sign 𐤊 GUR, while it is used only with volumes in

<sup>20</sup>This sign is sometimes interpreted as a measurement unit, and transliterated *iku*, see, e.g., [Pro20, pp. 385 sqq.], or transliterations in [Feu04] discussed in §3.7.2. Even with this interpretation, the sequence of numerals used, and the interpretation of numerals shared with other metrological systems, is specific to system  $G_{Ur III/QB}$ .






<sup>21</sup>As in the surface of the field of  (the city of Apisal) reported on [P102305, r. 1]

<sup>22</sup>From [P213162], which has an additional , two thirds (of a shekel), see §3.3.5.

<sup>23</sup>Used for volumes of grain, but also oil, dairy products, beer, etc., as well as to express the capacity of boats; volumes of earthworks instead use system  $G_{U_{rIII}/OB}$  based on a height of one cubit, see[[Pow87](#), p. 488; [Rob08](#), p. 294; [Rob19](#)].



excess of one gur, is written after the whole expression, after the overt unit sign **Ṣ** if present, and after the word for “grain” if present, as in

 354 gur   
  3 ban<sub>2</sub>   
  6   
  sila<sub>3</sub>   
  of grain.

Observe that while large numbers of gur follow<sup>25</sup> system  $S_{\text{Ur III/OB}}$ , the use of horizontal (AŠ) numerals for the gur disambiguates from the vertical bariga, as  $\langle \text{I} \text{—} \text{II} \rangle$  would be 10 gur 1 bariga, and  $\langle \text{—} \text{II} \rangle$  would be 11 gur; again even with some overt units, most of the numerals that participate in a metrological system have an interpretation dependent on that system.






This intertwining of units and numerals explains the large number of already-encoded numeral series:

- $\mathbb{I}-\mathbb{W}$  used in  $S_{\text{Ur III/OB}}$  and the SPVS as well as with overt units;
- $\mathbb{L}-\mathbb{X}$  used in  $G_{\text{Ur III/OB}}$ , of which  $\mathbb{L}-\mathbb{X}$  are also used in  $S_{\text{Ur III/OB}}$  and the SPVS as well as with overt units;
- $\mathbb{I}-\mathbb{W}$  used in  $S_{\text{Ur III/OB}}$ , and sometimes with overt units;
- $\mathbb{K}-\mathbb{W}$  used in  $S_{\text{Ur III/OB}}$ ;
- $\mathbb{O}-\mathbb{X}$  used in  $S_{\text{Ur III/OB}}$  and  $G_{\text{Ur III/OB}}$ ;
- $\mathbb{O}-\mathbb{X}$  used in  $S_{\text{Ur III/OB}}$  and  $G_{\text{Ur III/OB}}$ ;
- $\mathbb{L}-\mathbb{X}$  used in  $C_{\text{Ur III/OB}}$  as well as with overt units of the weight system;
- $\mathbb{L}, \mathbb{L}, \mathbb{L}, \mathbb{L}, \mathbb{L}$  used in  $C_{\text{Ur III/OB}}$ ;
- $\mathbb{I}, \mathbb{I}, \mathbb{I}, \mathbb{I}$  used in  $C_{\text{Ur III/OB}}$ —note the overlap with  $\mathbb{I}-\mathbb{W}$ ;
- $\mathbb{L}$  and  $\mathbb{L}$  used in  $G_{\text{Ur III/OB}}$ .

Only in the SPVS did numerals exist truly independently of metrology; to quote [Robo8, p. 78]: “The SPVS temporarily changed the status of numbers from properties of real-world objects to independent entities that could be manipulated without regard to [...] metrological system. [...] Once the calculation was done, the result was expressed in the most appropriate metrological units and thus re-entered the natural world as a concrete quantity.”

### 3.3.4 The length system

In the Ur III and Old Babylonian periods, lengths are expressed using overt units counted with 𐎶 and 𐎵 numerals with their system  $S_{\text{Ur III/OB}}$  values. Since it does not have any unusual numerals, this system would not in itself be of much relevance to character encoding, but we present it here as background for its Early Dynastic counterpart presented in §3.4. Metrological tables use the following units<sup>26</sup> [Fri07, p. 118; Rob19]:

 30 ←  60 ←  12 ←  30 ←  . ( $L_{\text{Ur III/OB}}$ )  
 danna      US<sup>27</sup>      nindan      kuš<sub>3</sub>      šu-si  
 būrum      cable      nindanum      ammatum      ubānum  
 league      360 m      rod      cubit      finger  
 10.8 km           6 m      50 cm      17 mm

<sup>24</sup>From [P309594, obv. 1 1].

<sup>25</sup>A larger unit, the guru<sub>7</sub> (*karûm*, grain heap), is sometimes used instead, with 𐎠𐎵𐎲𐎡𐏁 = 𐎧𐎶𐎷𐎺 (1 *karûm* = 3600 kurrū). See [Fri07, p. 415; Rob19].

<sup>26</sup>In this factor diagram and the next, we do not include the numerals. The units are no more than a factor of 60 apart, so higher numerals such as 𐎶 or 𐎠 are not used.

Two more units appear occasionally [Pow87, p. 459; Fri07, p. 118; Rob19]:

$$\begin{array}{ccccccc} \text{𐎶𐎵} & \xleftarrow{30} & \text{𐎶𐎵} & \xleftarrow{6} & \text{𐎶𐎵} & \xleftarrow{10} & \text{𐎶𐎵} & \xleftarrow{2} & \text{𐎶𐎵} & \xleftarrow{6} & \text{𐎶𐎵} & \xleftarrow{30} & \text{𐎶𐎵} & \text{𐎶𐎵} \\ & & & & \text{eše}_2 & & \text{gi} & & & & & & & \\ & & & & \text{ašlum} & & \text{qānum} & & & & & & & \\ & & & & \text{rope} & & \text{reed} & & & & & & & \\ & & & & 60 \text{ m} & & 3 \text{ m} & & & & & & & \end{array} \quad (\bar{L}_{\text{Ur III/OB}})$$

In addition, there are Akkadian names for the half-rope and half-reed, see [Pow87, pp. 463 sq.].

### 3.3.5 Fractions

Fractions of the *ikīm*,  $\searrow = \frac{1}{2}$  and  $\swarrow = \frac{1}{4}$ , have already been encountered. In other contexts, the fraction  $\frac{1}{2}$  is written  $\text{𐎶𐎵}$ , as in  $\text{𐎶𐎵} \text{𐎶𐎵}$ . The fractions  $\frac{1}{3}$  and  $\frac{2}{3}$  are written  $\text{𐎶𐎵}$  and  $\text{𐎶𐎵}$ . The latter two signs are derived from curviform signs  $\text{𐎶𐎵}$  and  $\text{𐎶𐎵}$ , which are already separately encoded; these are in turn derived from the sign  $\text{𐎶𐎵}$  (ŠU<sub>2</sub>), whose Early dynastic form resembles  $\text{𐎶𐎵}$ , and  $\text{𐎶𐎵}$  numerals; see [Pow71, pp. 113, 134]. The  $\text{𐎶𐎵}$  is sometimes omitted, as in [P240545, verso 6 9; P221530; P221531; P271238; P274845].

## 3.4 Curviform numerals in early metrologies

At first sight, the metrological systems from the Early Dynastic period resemble the ones previously mentioned. In particular, the discrete counting system used in the Early Dynastic period (and earlier in the fourth millennium) clearly mirrors system  $S_{\text{Ur III/OB}}$  [Fri07, p. 374; DE87, pp. 127, 165]:

$$\text{𐎶𐎵} \xleftarrow{10} \text{𐎶𐎵} \xleftarrow{6} \text{𐎶𐎵} \xleftarrow{10} \text{𐎶𐎵} \xleftarrow{6} \text{𐎶𐎵} \xleftarrow{10} \text{𐎶𐎵}. \quad (S)$$

Likewise the area system used in the Early Dynastic IIIb period for areas of one iku and greater [Dei22, p. 72; NDE93, p. 63; Fri07, p. 378; Lec16],

$$\text{𐎶𐎵} \xleftarrow{10} \text{𐎶𐎵} \xleftarrow{6} \text{𐎶𐎵} \xleftarrow{10} \text{𐎶𐎵} \xleftarrow{3} \text{𐎶𐎵} \xleftarrow{6} \text{𐎶𐎵} \quad (G_{\text{ED IIIb}})$$

mirrors system  $G_{\text{Ur III/OB}}$ , with consistent use of the numerals:  $\bullet$  corresponds to  $\text{𐎶𐎵}$ ,  $\text{𐎶𐎵}$  to  $\text{𐎶𐎵}$ , and  $\text{𐎶𐎵}$  to  $\text{𐎶𐎵}$ . An exception to this correspondence, noted in [L2/04-099, p. 4] (see §3.2), is that the vertical  $\text{𐎶𐎵}$  from  $S_{\text{Ur III/OB}}$  corresponds to a horizontal  $\text{𐎶𐎵}$  in system  $S$ . This is however far from the only case of such a reallocation of function. The earlier form of the area system is [DE87, pp. 141, 165; Fri07, p. 378]:

$$\text{𐎶𐎵} \xleftarrow{6} \text{𐎶𐎵} \xleftarrow{10} \text{𐎶𐎵} \xleftarrow{3} \text{𐎶𐎵} \xleftarrow{6} \text{𐎶𐎵}, \quad (G)$$

Observe that, as noted in [DE87, p. 142],  $\text{𐎶𐎵}$  changes meaning from  $10\bullet$  in system  $G$  to  $600\bullet$  in system  $G_{\text{ED IIIb}}$ . System  $G$  is used in the fourth millennium, but also in the ED I–II period (it is the “area 2” system in [Chao3], whereas  $G_{\text{ED IIIb}}$  is the “area 1” system).

Another example of nontrivial correspondence between cuneiform and curviform numerals may be found by comparing the fractions the Early Dynastic IIIb

<sup>27</sup>As indicated by the capitalization, the reading of this sign is unknown; see [Pow87, pp. 465 sqq.] for a discussion of various hypotheses.

area system<sup>28</sup>,

$$\odot \xleftarrow{10} \bullet \xleftarrow{6} \star \xleftarrow{10} \bullet \xleftarrow{3} \bullet \xleftarrow{6} \triangleright \xleftarrow{2} \triangleright \xleftarrow{2} \triangleright \xleftarrow{2} \star^{29}, \quad (G_{ED\ IIIb})$$

with the numerals of a contemporaneous capacity system:

$$\underbrace{\triangleright \xleftarrow{10} \triangleright \xleftarrow{6} \bullet \xleftarrow{10} \triangleright \xleftarrow{4} \triangleright \xleftarrow{6} \star}_{\text{gur san } \eta al_2} \quad (C_{\text{gur san } \eta al_2})$$

both described in [Lec16]. While the size of the  $\text{gur san } \eta al_2$  in bariga is different from that of the Old Babylonian  $\text{gur}$ , the basic structure of the capacity system is recognizable, with  $\triangleright$  corresponding to  $\uparrow$  for bariga,  $\star$ – $\star$  corresponding to  $\uparrow$ – $\star$  for ban<sub>2</sub>, and the  $\text{gur}$  counted with  $\triangleright$  rather than  $\leftarrow$  numerals. However, the half-iku is counted with the same  $\triangleright$  as the bariga, whereas it uses a different sign,  $\searrow$ , in the Old Babylonian system. As we will see, this cannot be handled as a split, by giving  $\searrow$  the glyph  $\triangleright$  in an Early Dynastic IIIb font, as the  $\searrow$  numeral series is also in use in that period.

### 3.4.1 Field lengths in Nirsu

The length system of the Early Dynastic IIIb state of Lagaš is of particular interest. As described in [Pow87, p. 466; Lec20, pp. 289 sq.], lengths are expressed in rods, but the unit sign  $\star$  is generally omitted; in addition, only tens of rods are used; these are equal to one rope, but the sign  $\text{gi}$  is not written either. Lengths shorter than one rope are expressed in half-rope using the  $\frac{1}{2}$  sign  $\star$  (again with no  $\text{gi}$ ), and then in reeds, *with* the sign  $\text{re}$ , as follows:

$$\star \xleftarrow{6} \star \xleftarrow{2} \star \xleftarrow{10} \star^{32} \quad (L_{ED\ IIIb})$$

$\frac{1}{2}$  eše<sub>2</sub>=10 nindan  
 1 rope=10 rods  
 60 m

$\text{gi}$   
 reed  
 3 m

This is the system that was used to express the sides of the field in [P020054] discussed in §3.2. In that tablet and most others from the same period, such as the ones discussed in [Lec20], areas are expressed in system  $G_{ED\ IIIb}$ , with curviform numerals<sup>33</sup>; in the absence of overt units, such as when dealing with length that are integer multiples of a half-rope<sup>34</sup>, the use of curviform or cuneiform numerals therefore disambiguates a numeric expression between an area and a length, and thus the interpretation of its numerals between systems  $G_{ED\ IIIb}$  and  $L_{ED\ IIIb}$ . The sign  $\text{re}$ , which would also disambiguate the interpretation as an area, is sometimes used after areas in ED IIIb Lagaš, but not systematically; in particular the area of the first field in [P020054] does not use this suffix. See [Lec20] for many examples with and without  $\text{re}$ . There are other such co-occurrences contrasting between metrological

<sup>28</sup>A variant is  $\odot \xleftarrow{10} \bullet \xleftarrow{6} \star \xleftarrow{10} \bullet \xleftarrow{3} \bullet \xleftarrow{6} \triangleright \xleftarrow{2} \triangleright \xleftarrow{2} \triangleright \xleftarrow{2} \star$ , see [Pow72, p. 218].

<sup>29</sup>The (fairly rare) cuneiform counterpart is  $\star$ .

<sup>32</sup>The reeds are counted using *tenû* numerals,  $\searrow$ ,  $\swarrow$ ,  $\nwarrow$ , etc.


<sup>33</sup>A [CDLI] search for "(bur3)" ( $\leftarrow$  numerals used for areas) currently returns 15 ED IIIb results, whereas one for "(bur3@c)" ( $\bullet$  numerals used for areas) returns 206. Further, when dated, the tablets with cuneiform bur<sub>3</sub> are from the reigns of  $\text{ur-inim-gi-na}$  (variously transliterated iri-inim-gi-na, uru-ka-gi-na, etc.) and  $\text{lugal-zag-ge-si}$  (lugal-zag-ge-si), the last two kings of ED IIIb Lagaš.

<sup>34</sup>This is the case of the sides of the field in [P020054, obv. ii 2–3].

systems; for instance, [Kre98, p. 303 n. 686] mentions the use of cuneiform numerals for days and months<sup>35</sup>.

### 3.4.2 Dyke lengths in Nirsu

[Pow87, p. 466] notes that reeds “are regularly written with the normal, cuneiform end of the stylus. Higher units are usually written with the reversed (round) end of the stylus.” Powell does not elaborate on the specifics of this mixed use of numerals, but a cursory search in [CDLI] finds many occurrences<sup>36</sup>, such as:

- [P221305, obv. 1 4]<sup>37</sup>                           

“pot”) of 20  $\text{𒍪}$ , with  $\text{𒍪}$  and  $\bullet$  numerals<sup>41</sup> for both the  $\text{𒍪}$  and the  $\text{𒍪}$ , thus [Pow87, pp. 504 sq.]

$$\begin{array}{c} \bullet \xleftarrow{10} \text{𒍪} \xleftarrow{2} \bullet \xleftarrow{10} \text{𒍪} \xleftarrow{\frac{3}{2}} \text{𒍪} \xleftarrow{2} \text{𒍪} \\ \hline \text{𒍪} \quad \text{𒍪} \end{array} \quad (C \text{ 𒍪})$$

but counts cheese ( $\text{𒍪}$ , ga’ar) using the  $\text{𒍪}$  capacity system, with  $\text{𒍪}$  numerals for the  $\text{𒍪}$ .

Another capacity system in ED IIIb Nirsu is the  $\text{𒍪}$   $\text{𒍪}$ , the gur of two ul [Lec16]:

$$\begin{array}{c} \bullet \xleftarrow{10} \text{𒍪} \xleftarrow{2} \text{𒍪} \xleftarrow{6} \text{𒍪} \xleftarrow{6} \text{𒍪} \\ \hline \text{𒍪} \text{ 𒍪} \end{array} \quad (C \text{ 𒍪} \text{ 𒍪})$$

Here the  $\text{𒍪}$ - $\text{𒍪}$ - $\text{𒍪}$  contrast occurs not only within the numerals of the system, but with its units; this is perhaps best illustrated by the expressions  $\text{𒍪}$   $\text{𒍪}$   $\text{𒍪}$   $\bullet$   $\text{𒍪}$   $\text{𒍪}$   $\text{𒍪}$  in [P221746, rev. 2 2] and  $\text{𒍪}$   $\text{𒍪}$   $\bullet$   $\text{𒍪}$   $\text{𒍪}$   $\text{𒍪}$  in [P221814, rev. 1 5].

### 3.4.4 Grain in Ebla

The mixing of curviform and cuneiform numerals within a metrological system is not specific to Nirsu.

The system of grain<sup>42</sup> capacities in Ebla uses the following units<sup>43</sup>:

$$\begin{array}{c} \text{𒍪} \text{ 𒍪} \xleftarrow{2} \text{𒍪} \text{ 𒍪} \xleftarrow{\frac{5}{2}} \text{𒍪} \xleftarrow{4} \text{𒍪} \text{ 𒍪} \xleftarrow{6} \text{𒍪} \text{ 𒍪} \\ \text{gu}_2\text{-bar} \quad \text{ba-ri}_2\text{-zu} \quad \text{gin}_4 \quad \text{nin}_2\text{-san}_3\text{su} \quad \text{an-zam}_x \end{array}$$

The  $\text{𒍪} \text{ 𒍪}$  and  $\text{𒍪} \text{ 𒍪}$  are generally counted using curviform numerals, and the smaller units using cuneiform  $\text{𒍪}$  numerals<sup>44</sup>. Indeed, a search on [EbDA] for co-

<sup>41</sup>This tablet also uses subtractive notation:  $\text{𒍪} \text{ 𒍪} \text{ 𒍪}$  “two pots minus two thirds (sila<sub>3</sub>)”,  $\bullet \text{ 𒍪} \text{ 𒍪} \text{ 𒍪}$  “ten minus one pots, six sila<sub>3</sub>”. Such subtractive notation is common in most of the metrological systems discussed here; it appears in the ED IIIa period [Rob08, p. 77]. It presents no complexity for character encoding, but it is noteworthy that the sign  $\text{𒍪}$  (lal, “minus”) is often ligated with the following numerals, with the subtrahend placed under a sometimes considerably enlarged  $\text{𒍪}$ , similar to the layout of the radical in modern mathematical notation, see, e.g., [P020092, rev. 3, 1, 2]. A good font could handle the very common  $-1$  case, perhaps even  $-2$  and  $-3$ ; setting arbitrary numeric expressions under the  $\text{𒍪}$ , or more generally replicating the layout of Early Dynastic tablets, is outside the realm of plain text; see also §6.2.

<sup>42</sup>Liquid capacities use a different system [Arc15, p. 229 n. 12]:

$$\begin{array}{c} \text{𒍪} \text{ 𒍪} \xleftarrow{30} \text{𒍪} \xleftarrow{6} \text{𒍪} \text{ 𒍪} \\ \text{la-ha} \quad \text{sila}_3 \quad \text{an-zam}_x \end{array}$$

A glance it seems that  $\text{𒍪}$  are counted with cuneiform numerals and higher units with curviform ones, thus

$$\begin{array}{c} \text{𒍪} \xleftarrow{\frac{5}{3}} \text{𒍪} \xleftarrow{6} \bullet \xleftarrow{10} \text{𒍪} \xleftarrow{3} \text{𒍪} \xleftarrow{10} \text{𒍪} \xleftarrow{6} \text{𒍪} \\ \hline \text{𒍪} \quad \text{𒍪} \end{array}$$

but we have not investigated this thoroughly.

<sup>43</sup>Another system uses different values for the  $\text{𒍪}$  and  $\text{𒍪}$ , see [Cha12, p. 62; Arc15, p. 229 n. 12]:

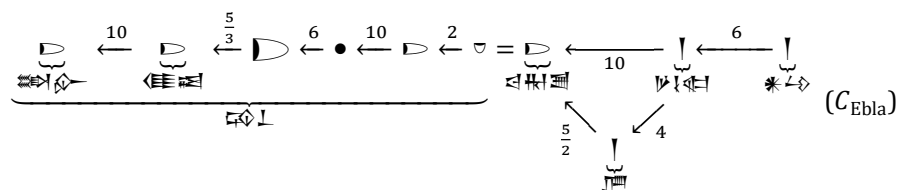
$$\text{𒍪} \text{ 𒍪} \xleftarrow{2} \text{𒍪} \text{ 𒍪} \xleftarrow{3} \text{𒍪} \xleftarrow{4} \text{𒍪} \text{ 𒍪} \xleftarrow{5} \text{𒍪} \text{ 𒍪}.$$

<sup>44</sup>As mentioned in [Cha12, p. 63], the  $\text{𒍪}$  is also counted using the  $\text{𒍪}$ - $\text{𒍪}$  numeral series. Some instances of that usage are found transliterated  $n/6$  in [EbDA]; in some cases the  $\text{𒍪}$  sign is omitted, and the  $\text{𒍪}$  numeral is then written before the  $\text{𒍪}$  unit, as in  $\text{𒍪} \text{ 𒍪} \text{ 𒍪}$  from [P240545, verso 1 3].

occurrences of either  $\mathbf{A} \rightarrow \mathbf{B}$  or  $\mathbf{B} \rightarrow \mathbf{A}$  with either of  $\mathbf{A} \rightarrow \mathbf{C}$  or  $\mathbf{B} \rightarrow \mathbf{C}$  finds the following expressions<sup>45</sup>:



1. [P240532, *verso* 4 9] 𠄎𠄎𠄎𠄎𠄎𠄎𠄎<sup>47</sup> 𠄎𠄎𠄎𠄎𠄎
2. [P240548, *verso* 11] 𠄎𠄎𠄎𠄎𠄎𠄎𠄎𠄎𠄎𠄎𠄎𠄎
3. [P240655, *recto* 7 9] 𠄎𠄎𠄎𠄎<sup>48</sup> 𠄎𠄎𠄎𠄎𠄎
4. [P240579, *verso* 4 3] 𠄎𠄎𠄎𠄎𠄎𠄎𠄎𠄎𠄎𠄎𠄎𠄎
5. [P240675, *verso* 2 2] 𠄎𠄎𠄎𠄎𠄎𠄎𠄎𠄎𠄎𠄎𠄎𠄎
6. [P240609, *verso* 3 1] 𠄎𠄎𠄎𠄎𠄎𠄎𠄎𠄎𠄎𠄎𠄎𠄎
7. [P240533, *recto* 3 3] 𠄎𠄎𠄎𠄎𠄎𠄎𠄎𠄎𠄎𠄎𠄎𠄎𠄎𠄎𠄎𠄎
8. [P240697, *recto* 15] 𠄎𠄎<sup>49</sup> 𠄎𠄎𠄎𠄎𠄎𠄎𠄎𠄎𠄎𠄎𠄎
9. [P240653, *recto* 6 2] 𠄎𠄎𠄎𠄎𠄎𠄎𠄎𠄎𠄎𠄎𠄎𠄎𠄎𠄎𠄎𠄎
10. [P240654, *recto* 2 6] 𠄎𠄎𠄎𠄎𠄎𠄎𠄎𠄎𠄎𠄎<sup>50</sup> 𠄎𠄎𠄎𠄎<sup>51</sup>
11. [P240531, *recto* 1 8] 𠄎𠄎𠄎𠄎𠄎𠄎𠄎𠄎𠄎𠄎𠄎𠄎𠄎𠄎𠄎𠄎
12. [P241708, *recto* 11]<sup>52</sup> 𠄎𠄎𠄎𠄎𠄎𠄎𠄎𠄎𠄎𠄎𠄎𠄎𠄎𠄎𠄎
13. [P241904, *recto* 11]<sup>53</sup> 𠄎𠄎𠄎𠄎𠄎𠄎𠄎𠄎𠄎<sup>54</sup> 𠄎𠄎𠄎𠄎𠄎
14. [P240964, *recto* 3 2]<sup>55</sup> 𠄎𠄎𠄎𠄎<sup>56</sup> 𠄎𠄎𠄎𠄎𠄎𠄎𠄎𠄎<sup>57</sup> 𠄎𠄎𠄎𠄎

Note that higher numbers of  $\text{𒀭} \perp$  are expressed in hundreds (*mi-at*  $\text{𒈹}$ ) and then thousands (*li-im*  $\text{𒂗}$ ), as is typical in Ebla [Arc15, p. 33], e.g., in the last example above or in [P240532, verso 2 3],  $\text{𐎲} \text{𐎠} \text{𐎵} \text{𐎶} : \text{𐎧} \text{𐎥} \text{𐎦} \text{𐎢} = 690$  (100 + 60 + 30 + 5 = 195  $\text{𒀭} \perp$  of grain). These expressions correspond to the following factor diagram:



### 3.4.5 Use in modern publications

Because of their prevalence in the fourth millennium and Early Dynastic period, the proposed numerals are widely used in modern publications discussing metrology

<sup>45</sup>We cite here only one attestation per tablet; most tablets contain several expressions mixing cuneiform  and larger with cuneiform  and smaller. In all cases the transcriptions given here are based on the [EbDA] transliterations, but the shape and orientation of the numerals was checked<sup>46</sup> on a photograph (from [EbDA] unless noted otherwise).

<sup>46</sup>As we will see in §3.7.2, [CDL] transliterations indicate numeral shape; however, as of this writing, they do so incorrectly on the Ebla corpus, claiming that all numerals are curviform, so we were not able to rely on them in this specific case.

<sup>47</sup>ba-ri<sub>2</sub>-zu<sub>2</sub>, a variant spelling.

<sup>48</sup>Short for   $\perp$ .

<sup>49</sup>Note the omitted  $\square \downarrow \perp$ .











<sup>50</sup>Instead of the expected  $\mathbb{V} \{ \mathbb{Q} \}$ .

<sup>51</sup>  not legible on the EbDA photo.

<sup>52</sup>From [CDLI] photo.

<sup>53</sup>From photo in [Arc89, p. 6].

<sup>54</sup>Laid out as `||||`; on stacking patterns see §6.2.

<sup>55</sup>From photo in [Arc89, p. 6]; see also the [CDLI] photo and the copy in [Fri86, p. 17]. This tablet features unusual usage of vertical numerals—"somewhat unorganized", as described by [Fri86, p. 16]—, such as    or   , but its   and   are consistently counted with cuneiform numerals, and the higher units with cuneiform numerals.

<sup>56</sup>Short for  .

<sup>57</sup>ŠU<sub>2</sub>+NIN<sub>2</sub>-san, an unusual variant spelling.

in those periods, as illustrated in Figures 1–20.

Since they contrast with the cuneiform numerals, they likewise appear contrastively in such publications. A remarkable example of that is found in Figure 20. The partial<sup>58</sup> transliteration “4  $\blacktriangleright$  ’ $a_3$ -da-um 4  $\blacktriangledown$  aktum 4  $\blacktriangleright$  ib<sub>2</sub><sup>tu<sub>9</sub></sup>×3! sa<sub>6</sub> gunu<sub>3</sub>” is used to illustrate a discussion of the interpretation of the contrast between  $\blacktriangleright$  and  $\blacktriangledown$  numerals. More conventional transliterations might omit the numeral shapes entirely, *e.g.*, 4 ’ $a_3$ -da-um 4 aktum 4 ib<sub>2</sub><sup>tu<sub>9</sub></sup>×3 sa<sub>6</sub> gunu<sub>3</sub>, which would obviously be inadequate in this context. There are transliteration conventions that are more explicit about numeral shape, *e.g.*, 4(aš<sup>c</sup>) ’ $a_3$ -da-um 4(diš<sup>c</sup>) aktum 4(aš<sup>c</sup>) ib<sub>2</sub><sup>tu<sub>9</sub></sup>×3(diš) sa<sub>6</sub> gunu<sub>3</sub>, but the result would be less readable. See §3.7.2 for a discussion of transliteration conventions for numerals.

for the words *šušanna* and *šannabi*. Deimel's reading *šann(a)* for *U* came out of the reading */šantak/* for the sign *Y* and the writing of *ša(-na)* after the fractional signs for *šušanna* and *šannabi* in Old Sumerian texts. But this was an ill-conceived argument at its inception, for

Figure 1: Discussion of the readings of proposed  $\nabla$  and already-encoded  $\nabla$  in [Pow71, p. 107].

sions also. In example 6, the writing ~~ḥ~~ may imply a reading /ḥ a n a b i/,<sup>1</sup> whereas ~~ḥ~~ in example 11 should be read \*/ḥ u ḥ a n a m i n/. Moreover, the question must be raised as to whether such writings as ~~ḥ~~ k ḥ - b a b b a r + ḥ a - a<sup>2</sup> do not perhaps imply a linguistic resolution of \*/ḥ u ḥ a n a m i n/ rather than /ḥ a n a b i/. I see no way of answering this question at present, but it is one which one

Figure 2: Discussion of the readings of proposed  and  as well as already-encoded  and  in [Pow71, p. 138].

<sup>58</sup>The untransliterated text would be 𐎠𐎡𐏁𐎧𐎥𐎵𐎤𐎢𐏃𐎶𐎺𐎠𐎫𐎲𐎠𐎣𐎪𐎨𐎦𐎱𐎮𐎭𐎬𐎴𐎩𐎻𐎼𐎽𐎾𐎿; note the atomically encoded  $\text{ib}_7 \times 3! = \text{M} \times \text{III} = \text{𐎠𐎡𐏁}$ .

1 "big cup" = 3 "big disks". Hence we can infer from the two SE-texts BIN 8,<sup>4</sup> and BIN 8,5 together, that the "SE-system" makes use of number signs whose values are related to each other through the equations

$$1\overline{\cup} = 3\circ, 1\circ = 10\bullet, 1\bullet = 6\overline{\cup}, 1\overline{\cup} = ?\overline{\cup}$$

A more convenient way of saying the same thing is to write out the "steps" between the various SE-units in what we shall call a "step-diagram" for the "SE-system":

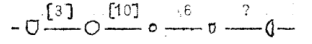


Figure 3: The first factor diagram, in [Fri78, p. 10].

$$\begin{cases} 4\overline{\cup} 5\bullet = 24\overline{\cup} 3\bullet & (\text{C 234}) \\ 5\overline{\cup} 1\bullet = 5\overline{\cup} 7\bullet & (\text{C 314}) \\ 1\overline{\cup} 1\overline{\cup} 1\overline{\cup} 1\overline{\cup} = 6\bullet 2\overline{\cup} 1\overline{\cup} & (\text{C 27}) \end{cases}$$

These metrological equations for the "unknowns"  $\overline{\cup}$ ,  $\bullet$ ,  $\overline{\cup}$ , etc., can be treated exactly as ordinary equations for unknowns  $x, y, z, \dots$ . In particular, the equations can be simplified by subtraction of equal amounts from both sides of the identities. In this way the three equations above can be reduced to:

$$\begin{aligned} 2\bullet &= 20\overline{\cup} & (4\overline{\cup} 3\bullet \text{ subtracted from both sides}) \\ 1\overline{\cup} &= 6\bullet & (5\overline{\cup} 1\bullet \text{ subtracted from both sides}) \\ 1\overline{\cup} &= 6\bullet 1\overline{\cup} 9\overline{\cup} & (1\overline{\cup} 1\overline{\cup} \text{ subtracted from both sides}) \end{aligned}$$

We can now read off from the first equation that  $1\bullet = 10\overline{\cup}$ , and from the second that  $1\overline{\cup} = 6\bullet$ . Then the third equation can be simplified (by "substitution" of these values into the equation), to the following reduced form:

$$1\overline{\cup} = 2\overline{\cup} 9\overline{\cup}.$$

The most likely solution to this last equation is, of course,

$$1\overline{\cup} = 2\overline{\cup}, \quad 1\overline{\cup} = 10\overline{\cup}.$$

Figure 4: The derivation of the factors of the bisexagesimal system in [Fri78, p. 15]<sup>60</sup>.

<sup>60</sup>The bisexagesimal system is used alike in proto-Elamite and proto-cuneiform texts, see [Fri78, p. 38]; the derivation in [Fri78, p. 15] is based on proto-Elamite artefacts. Note that in Friberg's early works [Fri78; Fri79; Fri86; Fri87], copies of fourth millennium and sometimes third millennium tablets are shown as vertical text (which they were for the scribes), and their numerals are written within horizontal text in the same orientation that they have if the tablet is taken as vertical text; in [UAX50] parlance, as if they had Vertical\_Orientation=Upright. In addition, they are listed in these equations in the horizontal order in which they appear as vertical text (thus the rightmost numeral is the most significant, read first). Cuneiform is correctly Vertical\_Orientation=Rotated, consistently both with modern practice and with the rotation between earlier vertical and later horizontal monumental inscriptions. Friberg's early conventions are not followed in later scholarship, and are abandoned in his own more recent works, such as [Fri07]; a more typical way to express the first equations might be

$$\begin{aligned} 5\bullet + 4\overline{\cup} &= 3\bullet + 24\overline{\cup} & (\text{C 234}) \\ 1\overline{\cup} + 1\bullet + 5\overline{\cup} &= 7\bullet + 5\overline{\cup} & (\text{C 314}) \\ 1\overline{\cup} + 1\overline{\cup} + 1\overline{\cup} &= 1\overline{\cup} + 2\overline{\cup} + 6\bullet & (\text{C 27}) \end{aligned}$$



Thus, for instance, the original set of fractions:  $\frac{1}{2}$ ,  $\frac{1}{4}$  and  $\frac{1}{8}$  of an iku) in the Sumerian GANA system, was after a time augmented through the addition of the new sub-unit SAR:  $\frac{1}{100}$  of an iku ( $\frac{1}{2}$ ). Similarly, the Sumerian weight unit "ma-na" which originally may have had only the sub-units  $\frac{1}{3}$  sa-na (= 1/3 mana) and  $\frac{2}{3}$  sa-na-bi (= 2/3 mana), and perhaps also gin:  $\frac{1}{60}$  (= 1/60 mana), seems to have acquired, at some time or other, also the smaller sub-units  $\frac{1}{3}$  gin, and  $\frac{1}{3} \times \frac{1}{60}$  gin).

Figure 5: Discussion of proposed fractions  $\frac{1}{2}$ ,  $\frac{1}{4}$ ,  $\frac{1}{8}$ , and  $\frac{1}{100}$ , as well as already-encoded  $\frac{1}{3}$  and  $\frac{2}{3}$  in [Fri78, p. 49].

stein publizierten Zeichenliste enthalten ist<sup>3</sup>, bis vor kurzem unentdeckt bleiben konnte. Erst 1978 machte der schwedische Mathematiker J. Friberg, ERM I, 9-11, darauf aufmerksam, daß die Zeichen für die Zahlen Eins ( $\square$ ) und Zehn ( $\bullet$ ) in Verbindung mit dem Zeichen SE nicht im Verhältnis 1 zu 10 sondern im Verhältnis 1 zu 6 stehen. Bis dahin hatte man, obwohl die Andersartigkeit des in Verbindung mit dem Zeichen SE verwendeten Zahlzeichensystems bekannt war, für diese beiden häufigsten Zahlzeichen einheitlich ein Verhältnis 1 zu 10 unterstellt, obwohl es mehrere eindeutige Gegenbelege gab, von denen zumindest diejenigen der Archaischen Texte aus Gendet Nasr bereits früh publiziert und jedermann zugänglich waren<sup>4</sup>. Als Folge

Figure 6: Discussion in [DE87, p. 117] of the discovery in [Fri78, pp. 9–11] (see Figure 3) of the different relations between  $\square$  and  $\bullet$  in systems G and ??.

there is in any case an important qualitative difference between IX for Latin novem and  $\bullet$  for Sumerian niš. niš seems to be a primary numberword requiring, in a system depicting Sumerian numeration, a differentiated representation comparable

Figure 7: The sign  $\bullet$  used in a parallel with IX in [Eng88, pp. 131–133 n. 9], discussing an argument from [Pow72, p. 172] on the question of the language of the Uruk III texts.

of decreasing fractions  $\frac{1}{n}$  of this measure, whereby "n" was determined by the number of oblique impressions made by the rounded end of a thin stylus around a central point in a specific sign. Thus  $\frac{1}{2} = \frac{1}{2} N_{30}$ ,  $\frac{1}{3} = \frac{1}{3} N_{30}$ , and so on. The first sign of the latter units,  $N_{34}$ ,

Figure 8: Description of the fractions  $\frac{1}{2}$  and  $\frac{1}{3}$  in [Eng98, p. 113]<sup>61</sup>.

A diplomatic edition of [Fri78] could rotate the numerals using a higher-level protocol:

$$\begin{cases} 4 \overline{\square} 5 \bullet = 24 \overline{\square} 3 \bullet & (C 234) \\ 5 \overline{\square} 1 \bullet 1 \overline{\square} = 5 \overline{\square} 7 \bullet & (C 314) \\ 1 \overline{\square} 1 \overline{\square} 1 \overline{\square} = 6 \bullet 2 \overline{\square} 1 \overline{\square} & (C 27). \end{cases}$$

<sup>61</sup>The text erroneously has  $N_{34}$  instead of  $N_{24}$ .

For instance, the first line contains the notations  $1N_{34}$   $1N_{300}$ ;  $2N_{20}$ , which can be translated "60 of the (grain rations containing)  $\ominus$  (of grain); (grain involved):  $2 \bullet$  (of ground barley)". This calculation contradicts the assumed numerical relationship  $10N_1 = 1N_{14}$ , since as was well known the measure represented by the sign  $N_{30}$  was  $1/5$  of that represented by  $N_1$ , so that  $60 \times 1/5 = 12$  and not 20, as  $2N_{14}$  would imply. Instead of relying on complicated

Figure 9: The sign  $\ominus$  used as a capacity measure within otherwise translated text in [Eng98, p. 116].

Die halbkreisförmigen Griffelindrücke gehen manchmal in mehr oder weniger eckige Formen über ( $\nabla$ )<sup>685</sup>. Es gibt aber auch Einer in Form von regelrechten – meist mehr oder weniger schräggestellten – Keilen ( $\searrow$ ), die öfters neben halbrunden Einern vorkommen und mit diesen kontrastieren<sup>686</sup>. Selten treten mit  $\nabla$  gebildete Zahlen auf<sup>687</sup> (sie entsprechen den bariga-Zahlen im Hohlmaßsystem, s.u. 7.4).

Figure 10: Discussion of co-occurrences and contrasts between  $\nabla$ ,  $\searrow$ , and  $\nabla$  in [Kre98, p. 303].

The calculations:

Obv. i	1	$60 \times 1/5 \nabla$	( $\ominus$ )	=	$12 \times \nabla$	=	$2 \times \bullet$		
	2	$120 \times 1/10 \nabla$	( $\Xi$ )	=	$12 \times \nabla$	=	$2 \times \bullet$		
	3	$120 \times 1/15 \nabla$	( $\searrow$ )	=	$8 \times \nabla$	=	$1 \times \bullet$	$2 \times \nabla$	
	4	$300 \times 1/20 \nabla$	( $\searrow$ )	=	$15 \times \nabla$	=	$2 \times \bullet$	$3 \times \nabla$	
	5	$600 \times 1/25 \nabla$	( $\searrow$ )	=	$24 \times \nabla$	=	$4 \times \bullet$		
Rev. i	1	1200			$1 \times \bullet$	$1 \times \bullet$	$5 \times \nabla$		
Obv. i	6	$6000 \times 1/30 \nabla$	(GAR+6N <sub>37</sub> )	=	$200 \times \nabla$	=	$1 \times \nabla$	$3 \times \bullet$	$2 \times \nabla$
ii	1	$120 \times \approx 1/4 \nabla$	(DUG <sub>a</sub> +U <sub>2a</sub> )	=	$30 \times \nabla$	=	$5 \times \bullet$	$1 \times \nabla$	$1 \times \searrow$
	2	$180 \times 1/5 \nabla$	(DUG+AS <sub>a</sub> )	=	$36 \times \nabla$	=	$6 \times \bullet$		
	3	$300 \times 1/15 \nabla$	(KAŠ <sub>a</sub> )	=	$20 \times \nabla$	=	$3 \times \bullet$	$2 \times \nabla$	
Rev. i	3	600			$1 \times \bullet$	$4 \times \bullet$	$3 \times \nabla$		$1 \times \searrow$
					$1 \times \bullet$	$1 \times \bullet$	$5 \times \nabla$		
					$1 \times \nabla$	$3 \times \bullet$	$2 \times \nabla$		
					$1 \times \bullet$	$4 \times \bullet$	$3 \times \nabla$	$1 \times \searrow$	
Grand total of groats used:					$1 \times \nabla$	$2 \times \bullet$	$9 \times \bullet$	$4 \times \nabla$	$1 \times \searrow$
Grand total of malt used:					$1N_{47}$	$4N_{20}$	$3N_5$	$1N_{42a}$	(rev. i 3) $\times 1/5 =$
						$8 \times \bullet$	$4 \times \nabla$	$1 \times \searrow$	

Figure 6. Transliteration and calculations of MSVO 4, 66.

Figure 11: Calculations from [P005468] transcribed in [Eng01, p. 132] using modern mathematical notation combined with some of the proposed characters.

strong similarities between “area” 1 and “area” 3 systems, the sign with two concentric discs ( $\odot$ , notated  $N_{50}$ <sup>27</sup>) remains problematic. It never appears in any numerical combination with the sign with a single disc ( $\bullet$ ),

Figure 12: Discussion of  $\odot$  and  $\bullet$ <sup>62</sup> in [Cha03, p. 6].

$1/15$ , etc., of gur, we would expect the metrogram gur to appear in sub-column ii. In a certain way, it does for larger measures: the notation  $\text{𒌦} \text{𒌦}$  could be understood as  $1 \frac{1}{5}$  gur.<sup>67</sup> However, the metrogram gur does not appear for lower measures. It would not be consistent to attribute different functions to the same grapheme, according to the relative importance (be it great or small) of the quantity, so the signs  $\text{𒌦}$  and  $\text{𒌦}$  cannot be considered klatmatograms.

Metrological tablets from the end of the 4<sup>th</sup> millennium (Nissen, Damerow and Englund 1993, 55-59, to *MSVO* 1, nos. 2-3) contain a discrete set of numerical signs with specific surface area reference:

$\text{𒌦}$  1(iku) represents a surface of 3600m<sup>2</sup>  
 $\text{𒌦}$  1(eše<sub>3</sub>) represents a surface of 21,600m<sup>2</sup>  
 etc.

The signs iku and eše<sub>3</sub> constitute by themselves measures of surface areas. These measures are usually followed by the sign GAN<sub>2</sub>, which means either surface or field and

Figure 13: Discussion of Old Babylonian<sup>64</sup> capacity and fourth millennium area measures in [Pro09, p. 9].

formed by only two signs  $\text{𒌦}$  and  $\text{𒌦}$ , repeated as many times as necessary; this type of notation is highly standardized. Second, the order of magnitude of the numbers noted in this system is not indicated: 1, 60, 60<sup>2</sup>, 60<sup>3</sup>, 1/60, 1/60<sup>2</sup>, etc. are written in the same way, with the vertical wedge  $\text{𒌦}$ . The third feature concerns the exact function of

Figure 14: Description of the SPVS in [Cha12, p. 58], using the already-encoded signs  $\text{𒌦}$  and  $\text{𒌦}$ .

one step. The scribes of the Early Dynastic Period (c. 2600 BC), for instance, represented the number 648,000 with:  $\text{𒌦} \text{𒌦} \text{𒌦}$  but never with the repetition  $\text{𒌦} \text{𒌦} \text{𒌦}$ .

Figure 15: Discussion of large numbers illustrated by  $\text{𒌦} \text{𒌦} \text{𒌦}$ <sup>65</sup> in [Cha12, p. 59]

repetition of the same sign refers to both the capacity unit signified—often but not necessarily written immediately afterwards—and its value. The units of measurement are written in descending order from left to right—just as we would write 3 km, 120 m, 50 cm. For example:

$\text{𒌦} \text{𒌦} \text{𒌦}$  še bar  $\text{𒌦}$  ba-ri-zu  
 '3 gubar (capacity units) and 1 parisu'.

Figure 16: Partial transliteration of [P240597, recto 5 3]  $\text{𒌦} \text{𒌦} \text{𒌦} \text{𒌦} \text{𒌦} \text{𒌦}$  in [Cha12, p. 61].

<sup>62</sup>The statement that these do not co-occur refers to the texts from ED I-II Ur; these signs co-occur both earlier and later in areas, with different relations as previously discussed.

<sup>64</sup>The cuneiform text is Unicode-encoded.

<sup>65</sup>Compare  $\text{𒌦} \text{𒌦}$  in system *G<sub>Ur</sub> III/0B*. Sign order can be variable in early texts, see [Fox16, p. 8]. See [Po10773], also discussed in [Fri07, p. 148], for an example of  $\text{𒌦} \text{𒌦}$ , and [P274845; P241764] for examples of  $n \text{ 𒌦}$ .














This is particularly true of the signs , ,  and , whose form explicitly denotes the fractions 1/6, 2/6, 3/6, and 4/6 of the barig capacity measure written  in Mesopotamia—also transcribed by Assyriologists as 1 bán, 2 bán, 3 bán, and 4 bán with reference to the bán measure worth 1/6 of the barig. At Ebla, the sign  is most often associated with the *parisu* measure, while the signs , ,  and  refer to 1, 2, 3,

Figure 17: Discussion in [Cha12, p. 64] of the relation between – and  in Mesopotamia and in Ebla.

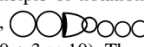

shape. The principle of notation is additive: each sign is noted as many times as necessary (e.g.,  transliterated as 2(šar<sub>2</sub>) 1(geš'u) 3(u), means  $2 \times 3600 + 1 \times 600 + 3 \times 10$ ). The system is based on an alternation of factors ten and

Figure 18: Explanation of the structure of the number  in [Pro20, p. 350].





might think of one fabric and a half,<sup>11</sup> but the presence of notations with “2 ”, “3 ”, and “6 ” (Fig. 1) elements excludes that one deals with fractions, as these notations are not consistent with those of Šuruppag’s weight measurement system.<sup>12</sup> The notation “1  gada” in o. ii 1 and r. vi 1, along with the total of “39



Fig. 1. Combinations of numerals attested in Š. 742.

Figure 19: Discussion of the contrast between  and  numerals in [Gor23, p. 162].






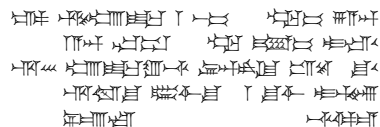
as, for example, in TM.75.G.3125 = ARET III 107 o. iv 1, “4  'a<sub>3</sub>-da-um<sup>tu9</sup>-2  4  aktum 4  ib<sub>2</sub><sup>tu9</sup> × 3  sa<sub>6</sub> gunu<sub>3</sub>” (Fig. 2).

Figure 20: Transliteration in [Gor23, p. 163] of [P242293, recto 4 1] incorporating untransliterated numerals.

### 3.5 Non-numeric usage



The beginning of the scribal art is a single wedge. That one has six pronunciations; it also stands for ‘sixty’<sup>66</sup>. Do you know its reading<sup>67</sup>?

Examenstext A

Many of the cuneiform numerals are used with a logographic or phonetic value. For example, the sign has, *inter alia*, the values aš, rum, and dili. While the horizontal numerals are most frequently written in the Early Dynastic period<sup>68</sup>, such non-numeric usage is almost<sup>69</sup> always written , for instance:

- in personal names in administrative texts, such as the following, which all contain numerals:
  - in [P010424, rev. 1 5; P010458, obv. 1 5; P010459, obv. 2 5'] from ED IIIa أبو صلابيخ,
  - in [P010960, obv. 2 5] from ED IIIa Šuruppag,
  - in [P251641, obv. 4 3] from ED IIIb Adab,
  - in [P252866, rev. 2 3] from ED IIIb Adab,
  - in [P298637, rev. 2 4] from ED IIIb Umma;
- in the Sumerian word u<sub>2</sub>-rum, “property” in ED IIIb Nirsu administrative texts which contain numerals, such as [P020006, obv. 2 3; P020008, rev. 1 2; P020018, rev. 1 2; P020024, obv. 1 4; P020030, obv. 3 1];
- in lexical texts:
  - in the divine name in the lexical texts [P010570, rev. 2 4; P010572, obv. 3 6], where the entries are prefixed with .
  - in the word dili, “small fish” in [P010578, obv. 2 5], witness to Early Dynastic Fish,
  - in the same word with a determinative, dili<sup>ku<sub>6</sub></sup>, in [P010586, obv. 4 4, 6], witness to Early Dynastic Food, which starts with numerals.

This is a clear contrast between and in this period, and genuine ambiguity can arise if it is lost; for instance, the personal name occurs on its own line in the aforementioned administrative texts; a line would instead be read as “one slave”.

### 3.6 The limited benefits of diachronic encoding for numerals

The argument in favour of diachronic encoding is that it facilitates interoperability in a variety of use cases, as we have outlined in §3.1. While these benefits are real and

<sup>66</sup>The reader will recall that ŋeš<sub>2</sub> is written , with a larger wedge than ; however, these signs have merged by the time Examenstext A is composed.

<sup>67</sup>Besides ŋeš<sub>2</sub>, a look at [OSL] shows that the values diš, ge<sub>3</sub>, makkaš, saṅtak<sub>4</sub>, and tal<sub>4</sub> are attested both in [ePSD2] and in lexical lists. The sign is also used for the Akkadian word *ana* in the Neo-Assyrian period.

<sup>68</sup>A [CDLI] search for “(asz@c)” finds 3296 ED texts, while a search for “(asz)” finds 81 ED texts, of which 46 also contain “(asz@c)”.

<sup>69</sup>Exceptions are discussed in §3.7.1.

now visible for cuneiform signs, similar considerations are not generally applicable to curviform numerals.

Diachronic reference works such as sign lists and dictionaries tend to not include numbers, or when they do, they treat them separately, and include signs such as  $\text{—}$  that have both numeric and non-numeric values in both the main list and the section on numbers. For instance, [Sch35, pp. 123 sqq.] lists all of  $\text{—}$ – $\text{—}$  together with  $\text{—}$ – $\text{—}$ , while  $\text{—}$ ,  $\text{—}$ , and  $\text{—}$ , and only those, appear at the beginning of the sign list, since they have non-numeric values<sup>70</sup>. [Cat13, p. 58] has the numeric signs  $\text{—}$ ,  $\text{—}$ ,  $\text{—}$ , whereas non-numeric  $\text{—}$  is at the beginning of the sign list, where its values *aš* and *rum* are listed. For signs with both non-numeric and numeric usage, [Dei22] writes *s. die Zahlz.* throughout the main list; LAK 1  $\text{—}$  thus reappears at LAK 829 together with  $\text{—}$ ,  $\text{—}$ , and  $\text{—}$ . One should note [Bor10], which has numbers throughout the sign list; but that sign list does not show glyphs predating the Old Babylonian period, nor does it comprehensively cover the numerals used in the Ur III and Old Babylonian periods, as, for instance, it does not have  $\text{—}$ – $\text{—}$  used in system  $G_{\text{Ur III/OB}}$ .

Composite texts rarely have witnesses both from the Early Dynastic period and later; the kinds of texts that do, chiefly lexical and literary texts, do not contain numbers to the extent that administrative texts do. Further, there tend to be changes<sup>71</sup> to the text between Early Dynastic and later witnesses that prevent a diachronic encoding of such composites. For numerals, the switch from  $\triangleright$  to  $\intercal$  numerals prevents diachronic encoding even if  $\triangleright$  were unified with  $\blacktriangleleft$ . For instance, the lexical list Early Dynastic Food, already mentioned in §3.5, contains some numbers, and has a witness from the Old Akkadian period covering these numbers: [P215653, a 1'–6']; however, they are written with  $\intercal$  numerals, whereas they are written with  $\triangleright$  numerals in the Early Dynastic witnesses; since  $\intercal$  and  $\blacktriangleleft$  are distinct<sup>72</sup> characters, the  $\triangleright$ - $\blacktriangleleft$  unification does not help.

More generally, since numbers are so deeply tied to metrology, and since metrological systems change between the Early Dynastic and later periods<sup>73</sup>, there is little opportunity for a diachronic representation of numeric quantities.

In the case of analyses such as [Rom23, sub “Adding Corpora”], it is interesting to note that numeric expressions are removed prior to the conversion of the corpus to Unicode cuneiform for further analysis.

<sup>70</sup>Non-numeric values of  $\multimap$  were discussed in §3.5;  $\multimap$  has the values  $\text{man}_3$  and  $\text{min}_5$ , and is used for the word *didli*, “several, various”;  $\multimap\multimap$  has the value  $\text{es}_6$ .

<sup>71</sup>Compare, e.g., in the *Instructions of Šuruppak*, 𒊩𒌆𒍪𒀭𒈾 / 𒊩𒌆𒍪𒀭𒉈 in the ED IIIa witness [P222243, obv. 2 7], also discussed in §3.7.1, and 𒊩𒌆𒍪𒀭𒉈 𒊩𒌆𒍪𒀭𒉈 in the OB composite [Q000782, 6] (translated “Šuruppak gave instructions to his son” in [ETCSL, t.5.6.1, 1–13]). It does not matter for the construction of a composite text whether this is encoded 𒊩𒌆𒍪𒀭 or 𒊩𒌆𒍪𒀭𒉈, since that word is absent from other witnesses, and since the surrounding words differ.

<sup>72</sup>Besides the contrasts in numeric usage mentioned in §3.3.3, these (already-encoded) characters were clearly not unifiable because of the many contrasts in non-numeric usage between them; several values of — which are not shared with † have already been mentioned, but perhaps most striking is the fact that, in the Neo-Assyrian period, — is used for the preposition *ina*, ‘in’, and † for the preposition *ana*, ‘to’.

<sup>73</sup>See, e.g., [Pow87, p. 493; Robo8, p. 55] on the unification of metrologies in the Old Akkadian period, resulting in the systems described in §3.3.

### 3.7 Compatibility considerations

A disunification twenty years after the fact, affecting all numerals, would ordinarily be a serious compatibility issue. Fortunately, with the exception of one character discussed below, we are not aware of any font using curviform glyphs for the already-encoded numerals. In fact we are not aware of any font designed for a style earlier than Old Babylonian, except for fonts mimicking the representative glyphs from the code charts, which are primarily Ur III, but sometimes earlier or later, as described in [UTR56, §2.4]. The lack of dedicated Ur III fonts may be explainable by the chart-like fonts<sup>74</sup> being good enough for most purposes; the lack of Early Dynastic fonts, by the aforementioned issues with numeral unification making the representation of any text with numerals intractable.

#### 3.7.1 The case of ŠAR<sub>2</sub>

The character U+122B9 CUNEIFORM SIGN ŠAR<sub>2</sub> has a circular reference glyph.

In most texts from the Early Dynastic IIIb and Old Akkadian period<sup>75</sup>, a contrast between non-numeric šar<sub>2</sub> written ◊ and numeric 1(šar<sub>2</sub>) written ● can be observed, similar to the contrast between — and ▷ previously discussed in §3.5. However, in lexical lists from Šuruppak and Ebla<sup>76</sup>, as well as in the *Stèle des vautours*, non-numeric šar<sub>2</sub> is curviform:

- \* 𐎶 𐎶 𐎶 𐎶 and \* 𐎶 𐎶 𐎶 𐎶 in [P010566, obv. 10 10, 11];
- ● 𐎶 𐎶 and \* 𐎶 𐎶 𐎶 𐎶 in [P010576, rev. 3 16, 17];
- ● 𐎶 𐎶 in [P240986, recto 3 3]<sup>77</sup>;
- ● 𐎶 𐎶 in [P222399, obv. 17 9, 18 11, 22 12]<sup>78</sup>.

It *would* be disruptive to the diachronic representation of text if non-numeric šar<sub>2</sub> were to have two different representations. The character U+122B9 CUNEIFORM SIGN ŠAR<sub>2</sub> should therefore be used in those cases, with its curviform glyph ◊, identical to the glyph of the proposed U+12579 CUNEIFORM NUMERIC SIGN ONE N45. Since the archaizing style of texts wherein non-numeric šar<sub>2</sub> is curviform solidly predates the transition from ● to ◊ in the relevant metrological systems, there is no need to represent a ◊-● contrast, so these characters can have the same glyph in specialist archaizing Early Dynastic fonts.

Since cuneiform U+122B9 CUNEIFORM SIGN ŠAR<sub>2</sub> effectively merges with U+1212D CUNEIFORM SIGN HI, the reference glyph should remain as it is, *i.e.*, curviform, so that the contrast between reference glyphs within the Cuneiform block remains clear; see [UTR56, §2.4]. Since system fonts follow the reference glyphs, and since extant specialist fonts target styles where U+122B9 is unambiguously cuneiform, there are no compatibility issues.

<sup>74</sup>Most prominently Noto Sans Cuneiform, a system font on both Windows—as part of Segoe UI Historic—and macOS.

<sup>75</sup>For example, in personal names:

- 𐎶 𐎶 𐎶 𐎶 in [P020019, rev. 1 2] from ED IIIb Nirsu;
- 𐎶 𐎶 𐎶 𐎶 in [P020182, obv. 2 9], also from ED IIIb Nirsu;
- 𐎶 𐎶 𐎶 in [P222186, obv. 3 3] from ED IIIb Umma;
- 𐎶 𐎶 𐎶 in [P235312, obv. 16] from Old Akkadian Umma.

<sup>76</sup>These are archaizing in other ways, *e.g.*, they have a 𐎶-𐎶 (NAM<sub>2</sub>-TUG<sub>2</sub>) split.

<sup>77</sup>From copy in [Man81, Elles 397].

<sup>78</sup>Note however \* 𐎶 𐎶 𐎶 𐎶 on [P222399, obv. 6 17], see Figure 21. Curviform non-numeric šar<sub>2</sub> is clearly archaizing in ED IIIb Nirsu; one might suppose that the scribe slipped into their modern ways here.



Figure 21: [P222399, obv. 6 16–17] 𒀭𒀭𒀭𒀭 / 𒀭𒀭𒀭𒀭.

Note that in rare cases, such as [P222243, obv. 2 7] from ED IIIa Adab, non-numeric 𒀭 (here with the value rum) is written 𒀭. It is out of scope for this proposal to decide whether such occurrences should be treated as anomalous spellings, encoded as U+12550 𒀭 cuneiform numeric sign one N01, or as stylistic distinctions, encoded as U+12038 CUNEIFORM SIGN ASH with a curviform glyph. In practice this would often be determined by the transliteration from which the cuneiform text is generated; it is noteworthy that as of this writing, the [CDLI] transliteration (UR2-1(aš@c)) and the [ePSD2] one (uru<sub>8</sub><sup>rum</sup>) of this word disagree on that aspect. Since 𒀭 has a cuneiform reference glyph, this does not pose any compatibility concerns.

### 3.7.2 Transliteration








An important feature of the encoding is that, in order to support input and bulk conversion of transliterated corpora to Unicode cuneiform, it should not represent distinctions that are finer than those recorded in typical transliterations; thus, while some older forms of BIL<sub>2</sub> can be described as 𒀭𒀭𒀭𒀭 NE×KASKAL or 𒀭𒀭𒀭𒀭 NE×PAP<sup>79</sup>, they are typically all transliterated bil<sub>2</sub>, and therefore are all represented by the character U+1224B 𒀭 CUNEIFORM SIGN NE SHESHIG, its name notwithstanding, as described in [UTR56, §2.5].









The situation is more complicated for numbers. Many transliterations do not represent the type of numeral used, instead interpreting the whole numeric expression and transcribing it with delimiters or units as needed to disambiguate. For instance, 𒀭𒀭𒀭𒀭 from [P305639, rev. 21] may be transliterated as 95 gur, as in [Feu04, vol. 2, p. 62]. The numerals may also be transliterated separately, but solely by their values in terms of the overt unit, as in [EbDA] transliterations: the aforementioned 𒀭𒀭𒀭𒀭 𒀭𒀭𒀭𒀭 𒀭𒀭𒀭𒀭 𒀭𒀭𒀭𒀭 𒀭𒀭𒀭𒀭 𒀭𒀭𒀭𒀭 𒀭𒀭𒀭𒀭 from [P240533, recto 3 3] is transliterated “20-1-1/2 gu<sub>2</sub>-bar 7 nig<sub>2</sub>-sagšu 2-1/2 an-zam<sub>x</sub><sup>80</sup> za”, reading both 𒀭 and 𒀭 as 1/2, but not distinguishing them.







































<sup>79</sup>As on [P249253].

<sup>80</sup>As of this writing, [EbDA] actually has an-zam<sub>x</sub>, with U+1D6A GREEK SUBSCRIPT SMALL LETTER CHI.



In particular, these transliterations do not differentiate between  $\neg$  and  $\downarrow$  numerals, nor between  $\triangleright$  and  $\triangleright$  numerals. For instance, the aforementioned [P242293, recto 4 1]      is transliterated “4 ‘a<sub>3</sub>-da-um<sup>tug<sub>2</sub></sup>-II 4 aktum<sup>tug<sub>2</sub></sup> 4 ib<sub>2</sub>-III gun<sub>3</sub> sa<sub>6</sub> <sup>tug<sub>2</sub></sup>” in [EbDA], with no distinction between the  and . Since  $\neg$  and  $\downarrow$  numerals are separately encoded, the numeric expressions in such transliterations cannot be transformed into Unicode cuneiform without additional context, regardless of curviform–cuneiform unification.

In metrological systems such as systems  $G_{Ur III/OB}$  and  $C_{Ur III/OB}$  where some units are indicated by the type of numeral rather than an overt unit sign, it is common practice to add the unit in parentheses in transliteration; for instance,  $\neg$      from [P386847, obv. 1] is transliterated “1(eše<sub>3</sub>) 5½ iku<sup>81</sup> 7 sar” in [Feu04, vol. 2, p. 176], and     from [P307255, obv. 12] is transliterated “1(n<sup>82</sup>) 2(b) 7 ½ sila<sub>3</sub>” in [Feu04, vol. 2, p. 151].

This practice has been generalized to systematically indicate numeral shape; this is in particular the case in [CDLI], where the transliterations of some of the above examples are “1(gešz2) 3(u) 5(asz) gur” for  $\downarrow$     , “1(esze3) 5(iku) 1/2(iku) GAN2 7(disz) sar” for  $\neg$                                      

cuneiform fonts, often within single numeric expressions. Further, if that contrast is lost in plain-text interchange, the text can be misinterpreted:  $\llcorner$  is a length of three ropes, but  $\bullet\bullet$  is an area of three bur<sub>3</sub>;  $\triangleright\updownarrow$  could be read as one  $\llcorner$  and one  $\updownarrow$ , where  $\triangleright\varnothing$  would be one and a half  $\llcorner$ ;  $\text{—}\llcorner$  is a personal name, but  $\triangleright\llcorner$  would be “one slave”.

In addition, there would be a risk of confusion about character identity should fontmakers attempt to treat the curviform and cuneiform numerals as unified. A designer concerned about the numeric-syllabic  $\triangleright\text{—}$  contrast, and wishing to support diachronic encoding between systems  $S_{\text{Ur III/OB}}$  and  $S$ , might give the  $\updownarrow$  numeral series (which is typically only used numerically in the Early Dynastic period) the glyphs of the  $\triangleright$  numeral series, since the clear  $\updownarrow\text{—}\triangleright$  identification involves the same rotation; this would however make it impossible to represent capacity measures that use  $\varnothing$ . Similarly, in an effort to support diachronic encoding for 1/2(iku), one might be tempted to give  $\text{—}$  the glyph of  $\varnothing$ , thereby rendering the font unusable for quantities measured using the  $\text{—}$  numeral series; an ED I–II Ur font designer could decide to give  $\text{—}$  the same glyph as  $\llcorner$  (that of the proposed  $\bullet$ ), according to the older area system, making it impossible to represent the newer system.

At the same time, contrary to most disunifications, the separate encoding of curviform numerals poses no serious compatibility issues for existing fonts or encoded corpora, nor does it, in general, introduce new issues with transliterated third millennium corpora. The oddity of  $\bullet$  requires some explanation, but does not pose any architectural issues, and is not fundamentally different from the other mergers and splits encountered in the cuneiform script.






## 4 Rationale for ED–Uruk numeral unification

A complete rationale for disunification between the non-numeric signs used in the fourth millennium and the already-encoded cuneiform signs will be given in the forthcoming proto-cuneiform encoding proposal. The core issue with extending the cuneiform script further back in time is that, since 1987, fourth millennium studies have used a different model of character identity and associated transliteration conventions, with names being given to structurally different glyphs, and no attempt being made at assigning phonetic values to them.

This is not a mere classification of glyph variants, as contrastive meanings of these systematic variants can often be reconstructed, with, *e.g.*, signs KAŠ<sub>a</sub>, KAŠ<sub>b</sub>, and KAŠ<sub>c</sub>, depicting filled jars with a spout (a), a handle (c), or neither (b), being understood as referring to containers of different substances, see [Eng01, pp. 34 sq.]. However, not all identified systematic variants are understood, and the general approach to character identity is closer to that used for undeciphered or partially deciphered scripts.






As part of the development of these conventions, a classification of fourth millennium numeric signs was developed; see [DE87]. This classification assigns to each unit numerals an identifier formed by the letter *N* with a numeric subscript (sometimes with an additional alphabetic subscript):  $N_1$  is  $\triangleright$ ,  $N_{14}$  is  $\bullet$ ,  $N_{34}$  is  $\triangleright$ , etc. Transliterations of numeric expression then use those to identify the type of number used, thus  $5N_1$  is  $\text{—}\triangleright$ , and  $5N_{14}$  is  $\bullet\bullet$ .

In contrast with the use of parenthetical unit names, this approach does not require interpreting the quantity being counted. This is valuable in contexts where

numerals are being used atypically, as conventional transliterations can otherwise force a dubious interpretation. For instance, the [CDLI] transliteration of   or   in [P283802, rev. 1 6, 2 2] currently uses (barig@c) for the vertical numerals, since  numerals are typically capacity measures; but [Gor23] interprets these instead as counting linen textiles. As a result, the fourth millennium conventions for numeral transliteration are used in Early Dynastic texts, especially those from the ED I–II period, even though the Sumerian text uses classical assyriological transliteration conventions; see [Cha03, p. 6 n. 27].

While the non-numeric signs are treated as undeciphered, the metrological systems used in the fourth millennium are well understood, as can be seen in [DE87, p. 165]. As a result, contrary to the non-numeric proto-cuneiform conventions, these numeric transliteration conventions are compatible with the classical ones described in §3.7.2; they are indeed used interchangeably, as in [P011104] which uses the notation u@f in [ePSD2], but N14@f in [CDLI]. Indeed, the numerals are used similarly in Early Dynastic metrological systems, and are visually identical.

A disunification of numerals between the third and fourth millennium would therefore induce confusion as to which numerals should be used in third millennium studies, and would needlessly duplicate the encoding of at least seventy characters; by splitting the attestations, these separate encoding proposals would run into additional difficulties to supply evidence for encoding.

Note that the structural variants designated by letters in fourth millennium notation have systematically been encoded, as they have occasionally be found to carry distinct numeric meaning. For instance,   $N_{30c}$  is listed as a variant of   $N_{30a}$  in [DE87, p. 166], where the numeric value of either in relation to   $N_{39a}$  is still unknown, but their values are found in [Eng04, p. 33] to be  $\frac{1}{10}$  , whereas  $\frac{1}{6}$  .

## 5 Considerations on individual numeral series


[TODO Document to the extent possible the metrological systems in which each sign is used. Note the disunification of N9 and N10 from 4(ban<sub>2</sub>@c) and 5(ban<sub>2</sub>@c).]

## 6 Characters not included in this proposal

### 6.1 Missing numerals

TODO “Ten of the sixty numerical signs contained in the list in figure 27, moreover, do not belong to any of the identified systems. Three of them were apparently scribbled by an awkward pupil. As to four of those remaining, we are not sure whether they constitute derivations of other, as yet unknown numerical signs or whether they are in fact numerical signs at all. For at least two of the ten signs, txi and we can affirm that each formed part of two additional systems, about which we know nothing due to the fact that no informative texts have been unearthed with notations in these systems.” [NDE93, p. 27] TODO N10 described as coming from P001319 which does not have it anymore. TODO N13 not attested in CDLI TODO ( $N_{17}$  not usefully numeric,  $12N_{14}$  not encodable, etc.). Cite [DE87, p. 147]  $N_{30C6}$  not attested 7 and 8(diš *tenû*) encodable, but not today; want to go into the Cuneiform Numbers and Punctuation block for sanity.



Figure 22: The layout of case [P011099, rev. 2 3]; the numeral  is rotated to fit the rounded corner of the tablet.

## 6.2 Stacking patterns

















































The already-encoded numerals in the Cuneiform Numbers and Punctuation block distinguish some *stacking patterns*; for instance 9<sup>1</sup> is encoded both as U+12446  and as U+1240E . This is in part due to contrastive usage of stacking patterns. For instance, besides  and  which are characteristic of bariga measures, four bariga is written  even where 4<sup>1</sup> is written , as in [P255010, obv. 2 3, rev. 1 17; P292843, obv. 4, rev. 5]. Another contrast is that between the stacking patterns used in scratch calculations in the SPVS, often                                            



Figure 23: The layout of case [P020066, obv. 1 1]; the numeral 22 is spread across two lines. The text is read in the order 22 1, “twenty-two oxen, one year old”.

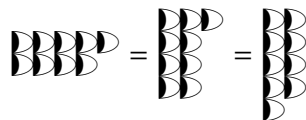


Figure 24: Three stacking patterns for U+12573 CUNEIFORM NUMERIC SIGN NINE N34. The one on the left is the reference glyph, used in Uruk III [P003499, obv. 1 1b; P004430, rev. 1 2], and widely afterwards, *e.g.*, ED IIIa Šuruppag [P010678, obv. 2], ED IIIb Nirsu [P020057, obv. 1 3], Old Akkadian Umma [P212464, obv. 11]. The ones in the middle and right are used in two Uruk IV tablets [P001243, rev. P004500, rev. 2]. All three Uruk examples are transliterated 9(N34) in [CDLI].

astic period, but that are also attested in the fourth millennium in the Uruk III period; the fourth millennium, especially the Uruk IV period, also frequently features numerals that use a more vertical layout, as illustrated in Figure 24. The later, more horizontal styles were chosen for two reasons: for the numerals used in the third and fourth millennium, usage in third millennium scholarship will be more frequent; and the horizontal layout poses fewer layout difficulties when set in lines of non-cuneiform text, as most modern scholarship is. Indeed, the absolute size of the indents 𐎶, 𐎶, •, and ● must remain consistent across the numeral series, lest a 𐎶 numeral be confused with an 𐎶 numeral. Since the single indents are frequently used in running text, as illustrated in §3.4.5, they need to be large enough that the vertical stacking patterns are impractical.

Variant stacking patterns, if needed, may be handled at a higher level as stylistic distinctions; Figure 24 uses OpenType stylistic alternates, and Figure 22 rotates the character 22, in both cases preserving the plain text backing.

### 6.3 Other glyph variants not reflected in transliteration

TODO Comment on the nameless variant glyphs from L2/23-190 and note that they are illustrating an even wider glyphic range as shown in [Eng01].

## Acknowledgements

TODO(egg): Something about the Vanséveren fonts

## References

### Artefacts

[P001243]	TODO. CDLI: <a href="#">P001243</a> .
[P003499]	TODO. CDLI: <a href="#">P003499</a> .
[P004430]	TODO. CDLI: <a href="#">P004430</a> .
[P004500]	TODO. CDLI: <a href="#">P004500</a> .
[P005468]	TODO. CDLI: <a href="#">P005468</a> .
[P010424]	TODO. CDLI: <a href="#">P010424</a> . ORACC: <a href="#">epsd2/P010424</a> .
[P010458]	TODO. CDLI: <a href="#">P010458</a> . ORACC: <a href="#">epsd2/P010458</a> .
[P010459]	TODO. CDLI: <a href="#">P010459</a> . ORACC: <a href="#">epsd2/P010459</a> .
[P010566]	TODO. CDLI: <a href="#">P010566</a> . ORACC: <a href="#">epsd2/P010566</a> . ORACC: <a href="#">dcclt/P010566</a> .
[P010570]	TODO. CDLI: <a href="#">P010570</a> . ORACC: <a href="#">epsd2/P010570</a> . ORACC: <a href="#">dcclt/P010570</a> .
[P010572]	TODO. CDLI: <a href="#">P010572</a> . ORACC: <a href="#">epsd2/P010572</a> . ORACC: <a href="#">dcclt/P010572</a> .
[P010576]	TODO. CDLI: <a href="#">P010576</a> . ORACC: <a href="#">dcclt/P010576</a> .
[P010578]	TODO. CDLI: <a href="#">P010578</a> . ORACC: <a href="#">dcclt/P010578</a> .
[P010586]	TODO. CDLI: <a href="#">P010586</a> . ORACC: <a href="#">dcclt/P010586</a> .

[P010678]      TODO.  
                  CDLI: [P010678](#).  
                  ORACC: [dccmt/P010678](#).

[P010773]      TODO.  
                  CDLI: [P010773](#).  
                  ORACC: [dccmt/P010773](#).

[P010876]      TODO.  
                  CDLI: [P010876](#).  
                  ORACC: [epsd2/P010876](#).

[P010960]      TODO.  
                  CDLI: [P010960](#).  
                  ORACC: [epsd2/P010960](#).

[P011099]      TODO.  
                  CDLI: [P011099](#).  
                  ORACC: [epsd2/P011099](#).

[P011104]      TODO.  
                  CDLI: [P011104](#).  
                  ORACC: [epsd2/P011104](#).

[P020006]      TODO.  
                  CDLI: [P020006](#).  
                  ORACC: [epsd2/P020006](#).

[P020008]      TODO.  
                  CDLI: [P020008](#).  
                  ORACC: [epsd2/P020008](#).

[P020016]      TODO.  
                  CDLI: [P020016](#).  
                  ORACC: [epsd2/P020016](#).

[P020018]      TODO.  
                  CDLI: [P020018](#).  
                  ORACC: [epsd2/P020018](#).

[P020019]      TODO.  
                  CDLI: [P020019](#).  
                  ORACC: [epsd2/P020019](#).

[P020024]      TODO.  
                  CDLI: [P020024](#).  
                  ORACC: [epsd2/P020024](#).

[P020030]      TODO.  
                  CDLI: [P020030](#).  
                  ORACC: [epsd2/P020030](#).

[P020054]      VAT 4731. [[För16](#), 40 p.14]. Vorderasiatisches Museum.  
                  CDLI: [P020054](#).  
                  ORACC: [epsd2/P020054](#).

[P020057]      TODO.  
                  CDLI: [P020057](#).  
                  ORACC: [epsd2/P020057](#).

[P020065]	<p>TODO.</p> <p>CDLI: <a href="#">P020065</a>.</p> <p>ORACC: <a href="#">epsd2/P020065</a>.</p>
[P020066]	<p>TODO.</p> <p>CDLI: <a href="#">P020066</a>.</p> <p>ORACC: <a href="#">epsd2/P020066</a>.</p>
[P020090]	<p>TODO.</p> <p>CDLI: <a href="#">P020090</a>.</p> <p>ORACC: <a href="#">epsd2/P020090</a>.</p>
[P020092]	<p>TODO.</p> <p>CDLI: <a href="#">P020092</a>.</p> <p>ORACC: <a href="#">epsd2/P020092</a>.</p>
[P020129]	<p>VAT 04713. Vorderasiatisches Museum.</p> <p>CDLI: <a href="#">P020129</a>.</p> <p>ORACC: <a href="#">epsd2/P020129</a>.</p>
[P020137]	<p>TODO.</p> <p>CDLI: <a href="#">P020137</a>.</p> <p>ORACC: <a href="#">epsd2/P020137</a>.</p>
[P020182]	<p>TODO.</p> <p>CDLI: <a href="#">P020182</a>.</p> <p>ORACC: <a href="#">epsd2/P020182</a>.</p>
[P102305]	<p>X.3.139. Michael C. Carlos Museum, Emory University.</p> <p>CDLI: <a href="#">P102305</a>.</p> <p>ORACC: <a href="#">epsd2/P102305</a>.</p>
[P142357]	<p>TODO.</p> <p>CDLI: <a href="#">P142357</a>.</p> <p>ORACC: <a href="#">epsd2/P142357</a>.</p>
[P142827]	<p>TODO.</p> <p>CDLI: <a href="#">P142827</a>.</p> <p>ORACC: <a href="#">epsd2/P142827</a>.</p>
[P212464]	<p>TODO.</p> <p>CDLI: <a href="#">P212464</a>.</p>
[P213162]	<p>TODO.</p> <p>CDLI: <a href="#">P213162</a>.</p> <p>ORACC: <a href="#">epsd2/P213162</a>.</p> <p>ORACC: <a href="#">dccmt/P213162</a>.</p>
[P215653]	<p>AS 15375 21. Musée du Louvre.</p> <p>CDLI: <a href="#">P215653</a>.</p> <p>ORACC: <a href="#">dcclt/P215653</a>.</p> <p>Louvre Collections: <a href="#">ark:/53355/cl010436723</a>.</p>
[P220927]	<p>TODO.</p> <p>CDLI: <a href="#">P220927</a>.</p> <p>ORACC: <a href="#">epsd2/P220927</a>.</p>



- [P221266] AO 13825. Musée du Louvre.  
CDLI: [P221266](#).  
ORACC: [epsd2/P221266](#).  
Louvre Collections: [ark:/53355/cl010138527](#).
- [P221291] AO 13850. Musée du Louvre.  
CDLI: [P221291](#).  
ORACC: [epsd2/P221291](#).
- [P221305] AO 13864. Musée du Louvre.  
CDLI: [P221305](#).  
ORACC: [epsd2/P221305](#).
- [P221530] TODO.  
CDLI: [P221530](#).  
ORACC: [epsd2/P221530](#).
- [P221531] TODO.  
CDLI: [P221531](#).  
ORACC: [epsd2/P221531](#).
- [P221746] TODO.  
CDLI: [P221746](#).  
ORACC: [epsd2/P221746](#).
- [P221814] TODO.  
CDLI: [P221814](#).  
ORACC: [epsd2/P221814](#).
- [P221815] TODO.  
CDLI: [P221815](#).  
ORACC: [epsd2/P221815](#).
- [P222186] TODO.  
CDLI: [P222186](#).  
ORACC: [epsd2/P222186](#).
- [P222243] TODO.  
CDLI: [P222243](#).  
ORACC: [epsd2/P222243](#).
- [P222399] *Stèle des vautours*. AO 50; AO 2346; AO 2347; AO 2348; AO 16109.  
Musée du Louvre.  
CDLI: [P222399](#).  
ORACC: [etcstri/Q001056](#).
- [P232278] *Gudea E*. AO 6. Musée du Louvre.  
CDLI: [P232278](#).  
ORACC: [etcstri/Q001544](#).
- [P232280] *Gudea G*. AO 7. Musée du Louvre.  
CDLI: [P232280](#).  
ORACC: [etcstri/Q001546](#).
- [P235312] TODO.  
CDLI: [P235312](#).  
ORACC: [epsd2/P235312](#).

- [P240531] TM.75.G.00265. Idlib, Syria: National Museum of Syria.  
CDLI: [P240531](#).  
EbDA: [1415](#).
- [P240532] TM.75.G.00266. Idlib, Syria: National Museum of Syria.  
CDLI: [P240532](#).  
EbDA: [1324](#).
- [P240533] TM.75.G.00267. Idlib, Syria: National Museum of Syria.  
CDLI: [P240533](#).  
EbDA: [1379](#).
- [P240545] TODO.  
CDLI: [P240545](#).
- [P240548] TM.75.G.00302. Idlib, Syria: National Museum of Syria.  
CDLI: [P240548](#).  
EbDA: [1350](#).
- [P240579] TM.75.G.00341. Idlib, Syria: National Museum of Syria.  
CDLI: [P240579](#).  
EbDA: [1364](#).
- [P240597] TODO.  
CDLI: [P240597](#).
- [P240609] TM.75.G.00440. Idlib, Syria: National Museum of Syria.  
CDLI: [P240609](#).  
EbDA: [1378](#).
- [P240653] TM.75.G.00535. Idlib, Syria: National Museum of Syria.  
CDLI: [P240653](#).  
EbDA: [1382](#).
- [P240654] TM.75.G.00536. Idlib, Syria: National Museum of Syria.  
CDLI: [P240654](#).  
EbDA: [1383](#).
- [P240655] TM.75.G.00537. Idlib, Syria: National Museum of Syria.  
CDLI: [P240655](#).  
EbDA: [1358](#).
- [P240675] TM.75.G.00557. Idlib, Syria: National Museum of Syria.  
CDLI: [P240675](#).  
EbDA: [1371](#).
- [P240697] TM.75.G.00579. Idlib, Syria: National Museum of Syria.  
CDLI: [P240697](#).  
EbDA: [1381](#).
- [P240964] TM.75.G.1392. Idlib, Syria: National Museum of Syria.  
CDLI: [P240964](#).  
ORACC: [dccmt/P240964](#).  
EbDA: [3184](#).
- [P240986] TODO.  
CDLI: [P240986](#).  
ORACC: [dcclt/P240986](#).

- [P241708] TM.75.G.02143. Idlib, Syria: National Museum of Syria.  
CDLI: [P241708](#).  
EbDA: [3173](#).
- [P241764] TODO.  
CDLI: [P241764](#).
- [P241904] TM.75.G.02346. [[Arc89](#), p. 6]. Idlib, Syria: National Museum of Syria.  
CDLI: [P241904](#).  
EbDA: [3183](#).  
ORACC: [dccmt/P241904](#).
- [P242293] TM.75.G.03125. Idlib, Syria: National Museum of Syria.  
CDLI: [P242293](#).  
EbDA: [217](#).
- [P249253] *Code de Hammurabi*. Sb 8. Musée du Louvre.  
CDLI: [P249253](#).
- [P251641] TODO.  
CDLI: [P251641](#).  
ORACC: [epsd2/P251641](#).
- [P252866] TODO.  
CDLI: [P252866](#).  
ORACC: [epsd2/P252866](#).
- [P255010] TODO.  
CDLI: [P255010](#).
- [P271238] TODO.  
CDLI: [P271238](#).  
ORACC: [epsd2/P271238](#).
- [P274845] TODO.  
CDLI: [P274845](#).
- [P283802] TODO.  
CDLI: [P283802](#).  
ORACC: [epsd2/P283802](#).
- [P292843] TODO.  
CDLI: [P292843](#).
- [P298637] TODO.  
CDLI: [P298637](#).  
ORACC: [epsd2/P298637](#).
- [P305639] TODO.  
CDLI: [P305639](#).
- [P307255] TODO.  
CDLI: [P307255](#).
- [P309594] TODO.  
CDLI: [P309594](#).  
ORACC: [epsd2/P309594](#).
- [P386847] TODO.  
CDLI: [P386847](#).

[Q000782] *The instructions of Šuruppag*. Composite text.  
 CDLI: [Q000782](#).  
 ORACC: [epsd2/Q000782](#).  
 ETCSL transliteration: [c.5.6.1](#); translation: [t.5.6.1](#).

## Unicode documents

- [L2/03-162] M. Everson and K. Feuerherm. *Basic principles for the encoding of Sumero-Akkadian Cuneiform*. 25th May 2003.  
 UTC: [L2/03-162](#).  
 ISO/IEC JTC 1/SC 2/WG 2: [N2585](#).
- [L2/03-393R] M. Everson, K. Feuerherm and S. Tinney. *Preliminary proposal to encode the Cuneiform script in the SMP of the UCS*. 3rd Nov. 2003.  
 UTC: [L2/03-393R](#).  
 ISO/IEC JTC 1/SC 2/WG 2: [N2664R](#).
- [L2/04-036] M. Everson, K. Feuerherm and S. Tinney. *Revised proposal to encode the Cuneiform script in the SMP of the UCS*. 29th Jan. 2004.  
 UTC: [L2/04-036](#).  
 ISO/IEC JTC 1/SC 2/WG 2: [N2698](#).
- [L2/04-099] L. Anderson. *Unification of Cuneiform Numbers*. 2004.  
 UTC: [L2/04-099](#).
- [L2/04-189] M. Everson, K. Feuerherm and S. Tinney. *Final proposal to encode the Cuneiform script in the SMP of the UCS*. 8th June 2004.  
 UTC: [L2/04-189](#).  
 ISO/IEC JTC 1/SC 2/WG 2: [N2786](#).
- [L2/12-208] M. Everson, C. Jay Crisostomo and S. Tinney. *Proposal for Early Dynastic Cuneiform*. 13th June 2012.  
 UTC: [L2/12-208](#).  
 ISO/IEC JTC 1/SC 2/WG 2: [N4278](#).
- [L2/23-190] A. Pandey. *Revised proposal to encode Proto-Cuneiform in Unicode*. 11th July 2023.  
 UTC: [L2/23-190](#).
- [L2/23-196] A. Pandey. *Proposal to encode Proto-Elamite in Unicode*. 18th Aug. 2023.  
 UTC: [L2/23-196](#).
- [L2/24-159] P. Constable, ed. *Minutes of UTC Meeting 180* (Redmond, 23rd–25th July 2024). 29th July 2024.  
 UTC: [L2/24-159](#).
- [UAX50] K. Lunde and K. Ishii, eds. *Unicode Vertical Text Layout*. Unicode Standard Annex #50. An integral part of *The Unicode Standard*. The Unicode Consortium.  
<https://www.unicode.org/reports/tr50/>.
- [Uni16] The Unicode Consortium. *The Unicode Standard*. Version 16.0.0. The Unicode Consortium, 10th Sept. 2024.  
 ISBN: 978-1-936213-34-4.  
<https://www.unicode.org/versions/Unicode16.0.0/core-spec/>.

- [UTR56] R. Leroy, ed. *Unicode Cuneiform Sign Lists*. Unicode Technical Report #56. The Unicode Consortium.  
<https://www.unicode.org/reports/tr56/>.

## Online corpora and related projects

- [CDLI] É. Pagé-Perron, J. L. Dahl, B. Lafont, J. Renn, R. K. Englund and P. Damerow, eds. *Cuneiform Digital Library Initiative*. 2000–.  
<https://cdli.mpiwg-berlin.mpg.de>.
- [DCCMT] E. Robson, ed. *The Digital Corpus of Cuneiform Mathematical Texts*. 2007–.  
 ORACC: [dccmt](https://oracc.org/dccmt).
- [EbDA] L. Milano, M. Maiocchi, F. Di Filippo, R. Orsini, E. Scarpa, M. Surdi et al., eds. *Ebla Digital Archives*. 2007–.  
<http://ebda.cnr.it/>.
- [eBL] E. Jiménez, Z. Földi, A. Härtinen, A. Heinrich, T. Mitto, G. Rozzi, I. Khait, J. Laasonen, F. Simonjetz et al., eds. *electronic Babylonian Library*. 2023–.  
<https://www.ebl.lmu.de/>.
- [ePSD2] S. Tinney, P. Jones and N. Veldhuis, eds. *The electronic Pennsylvania Sumerian Dictionary*. 2nd ed. 2017–.  
<http://oracc.org/epsd2>.
- [ETCSL] J. A. Black, G. Cunningham, J. Ebeling, E. Flückiger-Hawker, E. Robson, J. Taylor and G. Zólyomi, eds. *The Electronic Text Corpus of Sumerian Literature*. Oxford, 1998–2006.  
<http://etcsl.orinst.ox.ac.uk/>.
- [OSL] N. Veldhuis, S. Tinney et al., eds. *Oracc Sign List*. 2014–.  
<http://oracc.org/osl/>.

## Other documents

- [Arc15] A. Archi. *Ebla and Its Archives. Texts, History, and Society*. Studies in ancient Near Eastern records 7. Walter de Gruyter, 2015.  
 ISBN: 978-1-61451-716-0.  
 DOI: [10.1515/9781614517887](https://doi.org/10.1515/9781614517887).
- [Arc89] A. Archi. “Tables de comptes eblaïtes”. In: *Revue d'assyriologie et d'archéologie orientale* 83.1 (1989). Ed. by P. Amiet and P. Garelli, pp. 1–6. ISSN: 0373-6032.
- [Bor10] R. Borger. *Mesopotamisches Zeichenlexikon*. Alter Orient und Altes Testament 305. Ugarit-Verlag, 2010.
- [Cap02] R. Caplice. *Introduction to Akkadian*. 4th ed. Editrice Pontificio Istituto Biblico, 2002.  
 ISBN: 88-7653-566-7.
- [Cat13] A. Catagnoli. *La paleografia dei testi dell'amministrazione e della cancelleria di Ebla*. Quaderni di Semitistica 9. Università di Firenze, 2013.  
 ISBN: 8890134054.

- [Cha03] G. Chambon. “Archaic Metrological Systems from Ur”. In: *Cuneiform Digital Library Journal* 2003.5 (23rd Dec. 2003). ISSN: 1540-8779. [http://cdli.ucla.edu/pubs/cdlj/2003/cdlj2003\\_005.html](http://cdli.ucla.edu/pubs/cdlj/2003/cdlj2003_005.html).
- [Cha12] G. Chambon. “Numeracy and Metrology”. In: *The Oxford Handbook of Cuneiform Culture*. Ed. by K. Radner and E. Robson. Oxford University Press, 18th Sept. 2012, pp. 51–67. ISBN: 9780199557301. DOI: [10.1093/oxfordhb/9780199557301.013.0003](https://doi.org/10.1093/oxfordhb/9780199557301.013.0003).
- [DE87] P. Damerow and R. K. Englund. “Die Zahlzeichensysteme der archaischen Texte aus Uruk”. In: M. W. Green and H. J. Nissen. *Zeichenliste der archaischen Texte aus Uruk*. Archaische Texte aus Uruk 2. Gebr. Mann Verlag, 1987. Chap. 3, pp. 117–165. Repr. <https://cdli.mpiwg-berlin.mpg.de/files-up/publications/englund1987a.pdf>.
- [Dei22] A. Deimel. *Liste der archaischen Keilschriftzeichen von Fara*. Wissenschaftliche Veröffentlichungen der Deutschen Orient-Gesellschaft 40. J. C. Hinrichs’sche Buchhandlung, 1922.
- [Eng01] R. K. Englund. “Grain Accounting Practices in Archaic Mesopotamia”. In: *Changing Views on Ancient Near Eastern Mathematics*. Ed. by J. Høyrup and P. Damerow. Berliner Beiträge zum Vorderen Orient 19. Dietrich Reimer Verlag, 2001, pp. 1–35.
- [Eng04] R. K. Englund. “Proto-Cuneiform Account-Books and Journals”. In: *Creating Economic Order. Record-keeping, Standardization and the Development of Accounting in the Ancient Near East*. Ed. by M. Hudson and C. Wunsch. International Scholars Conference of Ancient Near Eastern Economies 4. CDL Press, 2004. Chap. 1, pp. 23–46.
- [Eng88] R. K. Englund. “Administrative Timekeeping in Ancient Mesopotamia”. In: *Journal of the Economic and Social History of the Orient* 31.2 (1988).
- [Eng98] R. K. Englund. “Texts from the Late Uruk Period”. In: *Mesopotamien. Späturuk-Zeit und Frühdynastische Zeit*. Orbis Biblicus et Orientalis 160/1. 1998, pp. 13–233. ISBN: 3-7278-1166-8.
- [Feu04] K. G. Feuerherm. “Abum-waqar and His Circle. A Prosopographical Study”. PhD thesis. University of Toronto, 2004.
- [För16] W. Förtsch. *Altbabylonische Wirtschaftstexte aus der Zeit Lugalanda’s und Urukagina’s*. Vorderasiatische Schriftdenkmäler der Königlichen Museen zu Berlin 14. J. C. Hinrichs, 1916.
- [Fox16] D. A. Foxvog. “Introduction to Sumerian Grammar”. In: *Cuneiform Digital Library Preprints* 2016.2 (4th Jan. 2016). <https://cdli.mpiwg-berlin.mpg.de/articles/cdlp/2.0>.
- [Fox22] D. A. Foxvog. “Elementary Sumerian Glossary (revised 2022)”. In: *Cuneiform Digital Library Preprints* 2022.3.1 (11th Apr. 2022). <https://cdli.mpiwg-berlin.mpg.de/articles/cdlp/3.1>.

- [Fri07] J. Friberg. *A Remarkable Collection of Babylonian Mathematical Texts*. Sources and Studies in the History of Mathematics and Physical Sciences. Springer, 2007. Manuscripts in the Schøyen Collection Cuneiform Texts 1. Manuscripts in the Schøyen Collection 6. ISBN: 978-0-387-34543-7.
- [Fri78] J. Friberg. *A Method for the Decipherment, through Mathematical and Metrological Analysis, of Proto-Sumerian and Proto-Elamite Semi-Pictographic Inscriptions*. The Third Millenium Roots of Babylonian Mathematics 1. Department of Mathematics, Chalmers University of Technology, 1978.
- [Fri79] J. Friberg. *The Early Roots of Babylonian Mathematics*. 2. Department of Mathematics, Chalmers University of Technology, 1979.
- [Fri86] J. Friberg. “Three Remarkable Texts from Ancient Ebla”. In: *Vicino Oriente* 6 (1986), pp. 3–25. ISSN: 0393-0300. The Early Roots of Babylonian Mathematics 3.
- [Fri87] J. Friberg. “Mathematik”. In: *Reallexikon der Assyriologie und vorderasiatischen Archäologie*. Ed. by D. O. Edzard. Vol. 7 Libanukšabaš–Medizin. 1987–1990, pp. 531–585.
- [Gor23] F. Gori. “On Lapis Lazuli and Linen in Šuruppak Texts. An Analysis Through the Lens of Ebla Studies”. In: *Studia Eblaitica* 9 (2023), pp. 160–166. ISSN: 2364-7124.
- [Hue11] J. Huehnergard. *A Grammar of Akkadian*. 3rd ed. Brill, 2011. ISBN: 978-1-57506-941-8.
- [JJ24] T. Jauhiainen and H. Jauhiainen. “Advancing Cuneiform Text Dating Through Automatic Analysis”. 69th Rencontre Assyriologique Internationale (8th–12th July 2024). 11th July 2024 14:00.
- [Kre98] M. Krebern timer. “Die Texte aus Fāra und Tell Abū Šalābiḥ”. In: *Mesopotamien. Späturuk-Zeit und Frühdynastische Zeit*. Orbis Biblicus et Orientalis 160/1. 1998, pp. 235–427. ISBN: 3-7278-1166-8.
- [Lec12] C. Lecompte. “Des chiffres et des digues: à propos de deux textes présargoniques de Ġirsu et d’une notation numérique inhabituelle”. In: *Altorientalische Forschungen* 39.1 (Dec. 2012), pp. 81–86. DOI: [10.1524/aof.2012.0006](https://doi.org/10.1524/aof.2012.0006).
- [Lec16] C. Lecompte. “ED IIIb metrology: texts from Lagaš”. In: *CDLI:wiki. A Library of Knowledge of the Cuneiform Digital Library Initiative*. 12th Apr. 2016. [https://cdli.ox.ac.uk/wiki/doku.php?id=ed\\_iii\\_metrological\\_systems](https://cdli.ox.ac.uk/wiki/doku.php?id=ed_iii_metrological_systems).
- [Lec20] C. Lecompte. “The Measurement of Fields During the Pre-sargonic Period”. In: *Mathematics, Administrative and Economic Activities in Ancient Worlds*. Ed. by C. Michel and K. Chemla. Why the Sciences of the Ancient World Matter 5. Springer, 2020. Chap. 8, pp. 283–344.
- [Man81] P. Mander. “Lista dei segni dei testi lessicali di Ebla”. In: *Testi lessicali monolingui della biblioteca L. 2769*. Ed. by G. Pettinato. Materiali epigrafici di Ebla 3. Napoli: Istituto universitario orientale, 1981, pp. 285–382.

- [Mol14] M. Molina. *Sargonic Cuneiform Tablets in the Real Academia de la Historia. The Carl L. Lippmann Collection*. Real Academia de la Historia, 2014.  
ISBN: 978-84-15069-71-3.
- [MV24] M. Maiocchi and S. Volpi. "Reassessing Economic History in the Early Dynastic Period. Sources, Methods, and Perspectives within the frame of the "Urban Economy Begins" Project". 69th Rencontre Assyriologique Internationale (8th–12th July 2024). 12th July 2024 16:00.
- [NDE93] H. J. Nissen, P. Damerow and R. K. Englund. *Archaic Bookkeeping. Early Writing and Techniques of Economic Administration in the Ancient Near East*. Trans. by P. Larsen. The University of Chicago Press, 1993.  
ISBN: 0-226-58659-6.
- [Oel22] J. Oelsner. *Der Kodex Hammu-rāpi*. dubsar 4. Zaphon, 2022.  
ISBN: 978-3-96327-008-6.
- [Pow71] M. Powell. "Sumerian Numeration and Metrology". PhD thesis. University of Minnesota, 1971.
- [Pow72] M. Powell. "Sumerian Area Measures and the Alleged Decimal Substratum". In: *Zeitschrift für Assyriologie und Vorderasiatische Archäologie* 62.2 (1972), pp. 165–221. ISSN: 0084-5299.
- [Pow75] M. Powell. In: *Journal of Cuneiform Studies* 27.3 (July 1975), pp. 180–188. Rev. of H. Limet. *Étude de documents de la période d'Agadé appartenant à l'Université de Liège*. Bibliothèque de la Faculté de Philosophie et Lettres de l'Université de Liège 206. Paris: Les Belles Lettres, 1973.
- [Pow87] M. Powell. "Maße und Gewichte". In: *Reallexikon der Assyriologie und vorderasiatischen Archäologie*. Ed. by D. O. Edzard. Vol. 7 Libanukšabaš–Medizin. 1987–1990, pp. 457–530.
- [Pro09] C. Proust. "Numerical and Metrological Graphemes: From Cuneiform to Transliteration". In: *Cuneiform Digital Library Journal* 2009.1 (22nd June 2009). ISSN: 1540-8779.  
[http://cdli.ucla.edu/pubs/cdlj/2009/cdlj2009\\_001.html](http://cdli.ucla.edu/pubs/cdlj/2009/cdlj2009_001.html).
- [Pro20] C. Proust. "Early-Dynastic Tables from Southern Mesopotamia, or the Multiple Facets of the Quantification of Surfaces". In: *Mathematics, Administrative and Economic Activities in Ancient Worlds*. Ed. by C. Michel and K. Chemla. Why the Sciences of the Ancient World Matter 5. Springer, 2020. Chap. 9, pp. 345–395.
- [Rob08] E. Robson. *Mathematics in Ancient Iraq. A Social History*. Princeton University Press, 2008.  
ISBN: 978-0-691-09182-2.
- [Rob19] E. Robson. "Oracc metrology guidelines". In: *Oracc: The Open Richly Annotated Cuneiform Corpus*. 18th Dec. 2019.  
ORACC: [doc/help/editinginatf/metrology/metrologicaltables](http://oracc.berkeley.edu/doc/help/editinginatf/metrology/metrologicaltables).
- [Rob22] E. Robson. "Overview of Metrological Systems". In: *The Digital Corpus of Cuneiform Mathematical Texts*. 2022.  
ORACC: [dccmt/Metrology](http://oracc.berkeley.edu/dccmt/Metrology).



- [Rom23] A. Romach. *Stylometric Analysis for Akkadian Cuneiform Texts*. 2023–. <https://github.com/ARomach/Cuneiform-Stylometry>.
- [Rom24] A. Romach. “The Neo Assyrian Land Sale Documents from Dur-Katlimmu. A Stylometric Analysis of Their Scribal Features”. 69th Rencontre Assyriologique Internationale (Helsinki, 8th–12th July 2024). 10th July 2024 12:00.
- [Sch10] W. Schramm. *Akkadische Logogramme*. Göttinger Beiträge zum Alten Orient 5. Universitätsverlag Göttingen, 2010.  
ISBN: 978-3-941875-65-4.  
DOI: [10.17875/gup2010-511](https://doi.org/10.17875/gup2010-511).
- [Sch35] N. Schneider. *Die Keilschriftzeichen der Wirtschaftsurkunden von Ur III*. Editrice Pontificio Istituto Biblico, 1935.
- [Svä+24] S. Svärd, M. Lorenzon, J. Töyräänvuori, J. Valk, T. Alstola, E. Bennett, R. Uotila and T. Auranne, eds. *RAI 69 Abstracts*. July 2024.  
[https://www.helsinki.fi/assets/drupal/2024-07/RaiAbstractBookAjoitettuJaPäiväty\\_1.pdf](https://www.helsinki.fi/assets/drupal/2024-07/RaiAbstractBookAjoitettuJaPäiväty_1.pdf).