

# Archaic cuneiform numbers

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## 1 Summary

This document proposes encoding some numerals used in the Uruk and Early Dynastic periods 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 section 2. Most of them were listed in [L2/23-190]; however, the present document provides a more detailed rationale for their encoding and additional information about their identity.

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 section 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 section 3, including compatibility considerations in section 3.7.

The overall picture of unifications and disunifications over time is illustrated in table 1. The Script\_Extensions property assignments in section 2.2 reflect the overlap.

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

<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”, 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.

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

## 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 [Powell1972] “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

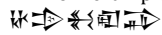
As outlined in, *e.g.*, [UTR56], the cuneiform encoding model is diachronic; each character may have wildly different glyphs depending on time period and region. For instance, the sign IM may resemble  in texts from Early Dynastic IIIa Šuruppag as in the character code charts,  later in the third millenium<sup>5</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>6</sup> and dictionaries<sup>7</sup>, and of composite texts<sup>8</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

<sup>5</sup>Merging with U+1224E CUNEIFORM SIGN NI2.

<sup>6</sup>Notably [OSL] and the online edition of [MZL] in [eBL, Signs].

<sup>7</sup>Notably [ePSD2] and the online edition of [Sch10] in [eBL, Dictionary].

<sup>8</sup>For example, there are Neo-Assyrian and Neo-Babylonian copies parts of the laws of , as well as Old Babylonian copies in both archaizing and cursive styles. Because of damage on the stele [P249253], some sections are known only from those copies. See [Oel22, pp. 110 sqq.].

has proven useful as a processing step in analyses such as [Rom24; JJ24]<sup>9</sup>. The diachronic approach is also useful for pedagogic applications<sup>10</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>11</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:

1(ḫeš <sub>2</sub> )	1(u)	1/2(diš)	5(diš tenû)	gi	us <sub>2</sub>	sa <sub>2</sub>
	7.5 (ropes)		5	reed	side	equal
3(u)	6(diš tenû)	gi	saṇ	sa <sub>2</sub>		
3 (ropes)	6	reed	front	equal		
ašag-bi	1(bur <sub>3</sub> )	1(eše <sub>3</sub> )	1(iku)	1/2(iku)		
ašag=bi						
field=DEM <sup>14</sup>						
				tug <sub>x</sub> (LAK483)	-si	-ga
				tugsiga	=ak	=am -Ø
				ploughed=GEN=COP-3.SG.S		

The argument made in [L2/04-099, p. 4] is that this is comparable to a stylistic distinction such as<sup>15</sup>

465 metres, equal lengths  
 198 metres, equal widths  
 this field is 9, 18 hectares of ploughed land

where the numerals have the same structure ([L2/04-099] contrasts this to the different structures of ASCII digits and roman numerals). That document further

<sup>9</sup>Attendees may recall the summary given on the third day of UTC #180, as recorded in [L2/24-159]. Other readers may refer to [Svā+24, pp. 242, 148].

<sup>10</sup>For instance, Old Babylonian grammar may be taught in the Neo-Assyrian script, as in [Cap02].

<sup>11</sup>At that time scoped to the repertoire of the Ur III period and later, see [L2/03-162, p. 1], although many disunifications, such as ≠ , were informed by Early Dynastic distinctions.

<sup>12</sup>As noted in [Pow87, p. 466], this sign has a very short “tail” in this period, so that it is wider than it is tall, and can at first seem like a large — in copies. The photos in CDLI clearly show that this is in fact a vertical wedge.

<sup>13</sup>Note that ED IIIb < numerals have a somewhat different appearance from those of the Ur III period used in this transcription; the sign in [P020054] looks more like Ur III .

<sup>14</sup>Alternatively: area=POSS.3.SG.NH, “its area”.

<sup>15</sup>We have taken the liberty of adjusting the analogy to use measures approximately equal to those in [P020054], instead of a field of five by twenty-five metres.

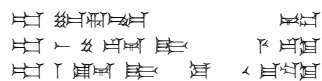
claims that “the number signs do not normally carry in their individual signs the meaning of what they are used to measure”, and that curviform and cuneiform numerals “are not normally mixed together in a single numerical expression”, noting the exceptions of [P232278; P232280]. In addition, [L2/04-099, p. 4] points out that the cuneiform numeric signs are descended from the curviform ones (this is undisputed), and claims there is only a small re-allocation of the function of signs (from  $\triangleright$  to  $\nabla$  numerals). It therefore comes to the conclusion that the use of curviform numerals should be seen as a formatting distinction, rather than one that should be represented in plain text, and insists that the encoding should capture the lineal historical descent of those signs, presumably to take advantage of the benefits of diachronic encoding described in section 3.1.

Although they had been part of the preliminary proposal [L2/03-393R], the curviform numerals were therefore removed from [L2/04-036] and [L2/04-189], which both state that “The distinction between curved numerals and their cuneiform descendants is treated as glyphic for the purposes of the present proposal; this issue will need to be revisited in subsequent encoding phases<sup>16</sup>.”

The time has come to revisit this issue. As we will see in section 3.3, numerals can only be interpreted in the context of what they measure, *i.e.*, as part of a metrological system. In section 3.4 we will see that in some periods:

- 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 contrast 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>17</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  $\nabla$ – $\text{𒌦}$ , the multiples of ten (10–50) are  $\text{𒌦}$ – $\text{𒌦}$ , but

<sup>16</sup>The cuneiform encoding process was planned in *stages* in [L2/03-162]. One might expect the second stage of encoding, which led to the creation of the Early Dynastic Cuneiform block, to incorporate the numerals needed for the representation and discussion of Early Dynastic texts; however, the proposal [L2/12-208] stated that “numerals have been omitted due to the complexity of numeral signs from this period. An expert in the metrology of this period must be consulted before these can be properly included.”

<sup>17</sup>See, *e.g.*, [Uni16, §22.3.3, sub “Cuneiform Numerals”].

the other digits 11–59 are sequences  $\leftarrow \text{I} - \text{XIII}$ ; 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  $\text{I} - \text{XIII}$ , tens  $\leftarrow - \text{XIII}$ , sixties  $\text{I} - \text{XIII}$  (with larger wedges than the units), multiples of six hundred  $\text{XIII} - \text{XIII}$ , multiples of three thousand six hundred  $\text{XIII} - \text{XIII}$ , and multiples of thirty-six thousand  $\text{XIII} - \text{XIII}$ .

### 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>18</sup>, where the number over arrow indicates the multiple of the preceding sign (right of the arrow) corresponding to the following sign (left).

$$\text{XIII} \xleftarrow{10} \text{XIII} \xleftarrow{6} \text{XIII} \xleftarrow{10} \text{I} \xleftarrow{6} \leftarrow \xleftarrow{10} \text{I} \quad (S_{\text{Ur III/OB}})$$

For example, the number 1729 = ((2 × 10 + 8) × 6 + 4) × 10 + 9 = 28 × 60 + 49 would be written  $\text{XIII} \text{XIII} \text{XIII} \text{XIII} \text{XIII}$  in the discrete counting system, and  $\leftarrow \text{XIII} \text{XIII} \text{XIII} \text{XIII}$  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 the approximate metric equivalent [Fri07, p. 378; Rob19]:

$$\text{XIII} \xleftarrow{10} \text{XIII} \xleftarrow{6} \text{XIII} \xleftarrow{10} \leftarrow \xleftarrow{3} \text{XIII} \xleftarrow{6} \text{XIII} \xleftarrow{2} \text{XIII} \xleftarrow{2} \text{XIII} \quad (G_{\text{Ur III/OB}})$$

$\text{bur}_3$ <i>būrum</i> 6,48 ha	$\text{eše}_3$ <i>eblum</i> 2,16 ha	$\text{iku}$ <i>ikûm</i> 3600 m <sup>2</sup>	$\text{ubûm}$  1800 m <sup>2</sup>
---	---	--	--

Note that for the range of areas given above<sup>19</sup>, this system does not use any symbols separate from the numerals for the individual units (*ubûm*, *ikûm*, *eblum*, and *būrum*). As mentioned in [Rob19], the whole numeric expression for the area would be followed by the sign  $\text{XIII}$  functioning as punctuation<sup>20</sup>, but the numerals are tied to the metrology; thus a surface of 5 *būr* 1 *ebel* 4 *ikû* (100 *ikû*, 36 ha) would be

<sup>18</sup>These diagrams, which have become standard in discussions of Mesopotamian metrology, originate with [Fri78, p. 10], where they are called *step-diagrams*.

<sup>19</sup>For areas smaller than a quarter *ikûm*, an overt unit is used, with 1 *mūšarum* (36 m<sup>2</sup>) written  $\text{I} \text{XIII}$ , equal to one hundredth of an *ikûm*, then sexagesimally subdivided in 60  $\text{I} \text{XIII}$  (shekels). For areas greater than 3600 *būrû*, the  $\text{XIII}$  and  $\text{XIII}$  numerals are reused with a suffix  $\text{XIII}$  (gal, Sumerian: big), as follows [Rob08, p. 295 n. b and c; Fri07, p. 378; Rob19]:

$$\text{XIII} \text{XIII} \xleftarrow{10} \text{XIII} \text{XIII} \xleftarrow{6} \text{XIII} \text{XIII} \xleftarrow{10} \text{XIII} \text{XIII} \xleftarrow{6} \text{XIII} \text{XIII} \xleftarrow{10} \leftarrow \xleftarrow{3} \text{XIII} \xleftarrow{6} \text{XIII} \xleftarrow{2} \text{XIII} \xleftarrow{2} \text{XIII} \xleftarrow{2,5} \leftarrow \xleftarrow{10} \text{I} \xleftarrow{6} \leftarrow \xleftarrow{10} \text{I}.$$

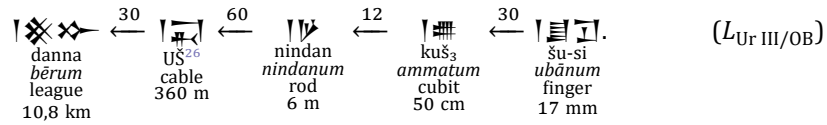
<sup>20</sup>This sign is sometimes interpreted as a measurement unit, and transliterated *iku*, see, e.g., [Proust2020], or transliterations in [Feu04] discussed in section 3.7.2. Even with this interpretation, the sequence of numerals used, and the interpretation of numerals shared with other metrological systems, is specific to system  $G_{\text{Ur III/OB}}$ .



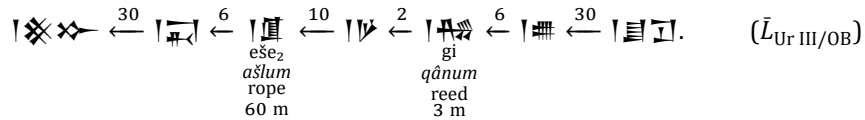
regard to [...] metrological system. [...] Once the calculation was done, the result was expressed in the most appropriate metrological units and thus re-entered the natural world as a concrete quantity.”

### 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  $S_{Ur\ III/OB}$  values<sup>25</sup>. 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 section 3.4. Metrological tables use the following units [Fri07, p. 118; Rob19]:



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



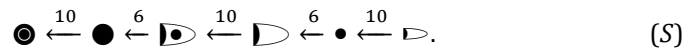
In addition, there are Akkadian names for the half-rope and half-reed, see [Pow87, pp. 463 sq.].

### 3.3.5 Fractions

Fractions of the *ikīm*,  $\frac{1}{2} = \frac{1}{2} \text{ —}$  and  $\frac{1}{4} = \frac{1}{4} \text{ —}$ , have already been encountered. In other contexts, the fraction  $\frac{1}{2}$  is written 𐎶, and the fractions  $\frac{1}{3}$  and  $\frac{2}{3}$  are written 𐎶 and 𐎶. The latter two signs are derived from curviform signs 𐎶 and 𐎶, which are already separately encoded; these are in turn derived from the sign 𐎶 ( $\$U_2$ ), whose Early dynastic form resembles 𐎶, and 𐎶 numerals; see [Powell1971]. The 𐎶 is sometimes omitted, as in [P240545; 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 Uruk period) clearly mirrors system  $S_{Ur\ III/OB}$  [Fri07, p. 374; DE87, pp. 127, 165]:



Likewise the area system used in the Early Dynastic IIIb period for areas of one *ikīm* and greater mirrors system  $G_{Ur\ III/OB}$  [LAK, p. 72; NDE93, p. 63; Fri07, p. 378;

<sup>25</sup>Adjacent units are no more than a factor of 60 apart, so higher numerals such as 𐎶 or 𐎶 are not used.

<sup>26</sup>As indicated by the capitalization, the reading of this sign is unknown; see [Pow87, pp. 465 sqq.] for a discussion of various hypotheses.



Lec16]:

$$\odot \xleftarrow{10} \bullet \xleftarrow{6} \star \xleftarrow{10} \bullet \xleftarrow{3} \blacktriangleright \xleftarrow{6} \blacktriangleright, \quad (G_{\text{ED IIIb}})$$

with consistent use of the numerals:  $\bullet$  corresponds to  $\blacktriangleleft$ ,  $\bullet$  to  $\blacktriangle$ , and  $\odot$  to  $\blacktriangle$ . An exception to this correspondence, noted in [L2/04-099, p. 4] (see section 3.2), is that the vertical  $\uparrow$  from  $S_{\text{Ur III/OB}}$  corresponds to a horizontal  $\blacktriangleright$  in system  $S$ . This is however far from the only case of such a reallocation of function. The earlier form of System  $G$  is [DE87, pp. 141, 165; Frio7, p. 378]:

$$\bullet \xleftarrow{6} \odot \xleftarrow{10} \bullet \xleftarrow{3} \blacktriangleright \xleftarrow{6} \blacktriangleright, \quad (G)$$

Observe that, as noted in [DE87, p. 142],  $\odot$  changes meaning from  $10\bullet$  in system  $G$  to  $600\bullet$  in system  $G_{\text{ED IIIb}}$ . System  $G$  is used in the Uruk period, but also in the ED I–II period (it is the “area 2” system in [Cha03], 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 area system<sup>27</sup>,

$$\odot \xleftarrow{10} \bullet \xleftarrow{6} \star \xleftarrow{10} \bullet \xleftarrow{3} \blacktriangleright \xleftarrow{6} \blacktriangleright \xleftarrow{2} \blacktriangleright \xleftarrow{2} \blacktriangleright \xleftarrow{2} \blacktriangleright \blacktriangleright^{28}, \quad (G_{\text{ED IIIb}})$$

with the numerals of a contemporaneous capacity system:

$$\underbrace{\blacktriangleright \xleftarrow{10} \blacktriangleright \xleftarrow{6} \bullet \xleftarrow{10} \blacktriangleright \xleftarrow{4} \blacktriangleright \xleftarrow{6} \blacktriangleright}_{\text{gur san } \eta\alpha_2} \quad (C_{\text{ED IIIb}})$$

both described in [Lec16]. While the size of the  $\text{gur san } \eta\alpha_2$  in bariga is different from that of the Old Babylonian  $\text{gur}$ , the basic structure of the capacity system is recognizable, with  $\blacktriangleright$  corresponding to  $\uparrow$  for bariga,  $\blacktriangleright$ – $\blacktriangleright$  corresponding to  $\uparrow$ – $\uparrow$  for ban<sub>2</sub>, and the  $\text{gur}$  counted with  $\blacktriangleright$  rather than  $\blacktriangleright$  numerals. However, the half-*ikûm* is counted with the same  $\blacktriangleright$  as the bariga, whereas it uses a different sign,  $\blacktriangleright$ , in the Old Babylonian system. As we will see, this cannot be handled as a split, by giving  $\blacktriangleright$  the glyph  $\blacktriangleright$  in an Early Dynastic IIIb font, as the  $\blacktriangleright$  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  $\blacktriangleright$  is generally omitted; in addition, only tens of rods are used; these are equal to one rope, but the sign  $\blacktriangleright$  is not written either. Lengths shorter than one rope are expressed in half-ropes using the  $\frac{1}{2}$  sign  $\blacktriangleright$  (again with no  $\blacktriangleright$ ), and then in reeds, with the sign  $\blacktriangleright$ . Effectively, this yields the following factor diagram:

$$\begin{array}{c} \uparrow \xleftarrow{6} \blacktriangleleft \xleftarrow{2} \blacktriangleleft \xleftarrow{10} \blacktriangleleft \blacktriangleleft^{31} \\ \text{1 eše}_2 = 10 \text{ nindan} \\ \text{1 rope} = 10 \text{ rods} \\ \text{60 m} \end{array} \quad \begin{array}{c} \text{gi} \\ \text{reed} \\ \text{3 m} \end{array} \quad (L_{\text{ED IIIb}})$$

<sup>27</sup>A variant is  $\odot \xleftarrow{10} \bullet \xleftarrow{6} \star \xleftarrow{10} \bullet \xleftarrow{3} \blacktriangleright \xleftarrow{6} \blacktriangleright \xleftarrow{2} \blacktriangleright \xleftarrow{2} \blacktriangleright \xleftarrow{2} \blacktriangleright$ , see [Powell1972].

<sup>28</sup>The cuneiform counterpart is  $\blacktriangleright$ .



### 3.4.3 Cheese and wheat in Nirsu

A similar mixture of cuneiform and curviform numerals may be observed with the capacity system; indeed, the previously described  $\text{𒍪 𒍪 𒍪}_3$  system uses  $\setminus$  numerals for  $\setminus$  [Fri78, p. 43; Lec16]:

$$\underbrace{\text{𒍪} \leftarrow^{10} \text{𒍪} \leftarrow^6 \bullet \leftarrow^{10} \text{𒍪} \leftarrow^4 \text{𒍪} \leftarrow^6 \text{𒍪} \leftarrow^6 \setminus \setminus}_{{\text{𒍪 𒍪 𒍪}_3}}, \quad (C_{\text{𒍪 𒍪 𒍪}_3})$$

as in [P020016; P020065; P020090; P020092; P020137] and others, where  $\text{ban}_2$  counted with  $\text{𒍪}$  numerals are followed by  $\text{sil}_3$  counted with  $\setminus$  numerals. Curviform numerals are also used to count  $\text{sil}_3$ , but not<sup>40</sup> in combination with larger units. This contrast can be seen in [P220927], which counts butter ( $\text{𒍪}$ ,  $i_3$ ) in  $\text{𒍪 𒍪 𒍪}_3 \setminus$ ,  $\text{𒍪 𒍪 𒍪}_3 \setminus$ , and  $\text{𒍪 𒍪 𒍪}_3 \bullet \text{𒍪 𒍪}_3 \setminus$ , pots of six, eight, and twelve  $\text{sil}_3$ , themselves counted using the discrete counting system<sup>41</sup>, but counts cheese ( $\text{𒍪}$ , ga'ar) using the  $\text{𒍪 𒍪 𒍪}_3$  capacity system, with  $\setminus$  numerals for the  $\text{sil}_3$ .

It is not only pots that come in multiple sizes in ED IIIb Nirsu, but also  $\text{𒍪}$ . Another capacity system is the  $\text{𒍪} \leftarrow \text{𒍪}$ , the gur of two ul:

$$\underbrace{\bullet \leftarrow^{10} \text{𒍪} \leftarrow^2 \text{𒍪} \leftarrow^6 \text{𒍪} \leftarrow^6 \setminus \setminus}_{{\text{𒍪} \leftarrow \text{𒍪}}}. \quad (C_{\text{𒍪} \leftarrow \text{𒍪}})$$

Here the  $\text{𒍪} \leftarrow \setminus \text{𒍪}$  contrast occurs not only within the numerals of the system, but with its units; this is perhaps best illustrated by the expressions  $\text{𒍪 𒍪 𒍪}_3 \bullet \text{𒍪 𒍪}_3 \setminus \text{𒍪} \leftarrow \text{𒍪}$  in [P221746] and  $\text{𒍪 𒍪 𒍪}_3 \bullet \text{𒍪 𒍪}_3 \setminus \text{𒍪} \leftarrow \text{𒍪}$  in [P221814].

### 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>:

$$\text{gu}_2\text{-bar} \leftarrow^2 \text{ba-ri}_2\text{-zu} \leftarrow^{\frac{5}{2}} \text{nin}_4 \leftarrow^4 \text{nin}_2\text{-sagšu} \leftarrow^6 \text{an-zam}_x.$$

<sup>40</sup>As of this writing, the single occurrence of (ban2@c) followed by curviform numerals and  $\text{sil}_3$  in CDLI, 4(ban2@c) 3(asz@c)  $\text{sil}_3$  in [P221815], is incorrect: it should be 4(ban2@c) 3(disz@t)  $\text{sil}_3$ .

<sup>41</sup>Including the fraction  $\frac{1}{3}$ , and with subtractive notation, *e.g.*,  $\text{𒍪 𒍪}_3 \text{𒍪}$  “two pots (of one  $\text{sil}_3$ ) minus one third (pot)”, or in the total,  $\bullet \text{𒍪 𒍪}_3 \text{𒍪 𒍪}_3 \setminus$  ten minus one pots of six  $\text{sil}_3$ . Such subtractive notation is common in most of the metrological systems discussed here; it appears in the ED IIIa period [Robo8, p. 77], but it presents no complexity for character encoding. The sign  $\text{𒍪}$  ( $\text{la}_2$ , “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 [P020092].

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

$$\text{la-ha} \leftarrow^{30} \text{sil}_3 \leftarrow^6 \text{an-zam}_x.$$

At a glance it seems that  $\setminus$  are counted with cuneiform numerals and higher units with curviform ones, thus

$$\text{𒍪 𒍪}_3 \leftarrow^{\frac{5}{2}} \text{𒍪} \leftarrow^6 \bullet \leftarrow^{10} \text{𒍪} \leftarrow^3 \text{𒍪} \leftarrow^{\frac{10}{3}} \text{𒍪} \leftarrow^6 \text{𒍪 𒍪}_3,$$

but we have not investigated this thoroughly.

<sup>43</sup>TODO mention the other one citing Chambon and the footnote in Archi



$$\begin{cases} 4\overline{0}5\overline{0} = 24\overline{0}3\overline{0} & (C\ 234) \\ 5\overline{0}1\overline{0}1\overline{0} = 5\overline{0}7\overline{0} & (C\ 314) \\ 1\overline{0}1\overline{0}1\overline{0} = 6\overline{0}2\overline{0}1\overline{0} & (C\ 27) . \end{cases}$$

These metrological equations for the "unknowns"  $\bar{U}$ ,  $\sigma$ ,  $\bar{V}$ , etc., can be treated exactly as ordinary equations for unknowns  $x$ ,  $y$ ,  $z$ ,... . 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:

$$\begin{array}{ll} 20 = 20 & (4 \text{ } 30 \text{ subtracted from both sides}) \\ 17 = 60 & (5 \text{ } 10 \text{ " " " }) \\ 19 = 60 + 17 - 9 & (1 \text{ } 19 \text{ " " " }) \end{array}$$

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

$$1 \bowtie = 2 \cup 9 \bowtie.$$

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

$$1 \text{ } \bowtie = 2 \text{ } \cup , \quad 1 \text{ } \boxtimes = 10 \text{ } \bowtie .$$

Figure 1: TODO [Fri78, p. 15]

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:  $\frac{1}{160}$ , equal to  $\frac{1}{100}$  of an iku ( $\frac{1}{100}$ ). Similarly, the Sumerian weight unit "na-na" which originally may have had only the sub-units  $\frac{1}{3}$  sa-na (=  $\frac{1}{3}$  mana) and  $\frac{2}{3}$  sa-na-bi (=  $\frac{2}{3}$  mana), and perhaps also  $\frac{1}{60}$  na-na, seems to have acquired, at some time or other, also the smaller sub-units

 (= 1/3 gin), and  - še (= 1/3 × 1/60 gin).

Figure 2: TODO [Fri78, p. 49]

partial<sup>54</sup> transliteration “4▷ ’a<sub>3</sub>-da-um 4▽ aktum 4▷ 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 ▷ and ▽ numerals. More conventional transliterations<sup>55</sup> might omit the numeral shapes entirely, e.g., 4 ’a<sub>3</sub>-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<sub>3</sub>-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<sup>c</sup>) sa<sub>6</sub> gunu<sub>3</sub>, but the result would be less readable. See Section 3.7.2 for a discussion of transliteration conventions for numerals.

[illegible]

<sup>55</sup>TODO cite the EbDA one.

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

Figure 3: TODO [Englund1988]

of decreasing fractions  $1/n$  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  $\Xi = 1/2 N_{39}$ ,  $\tilde{\Xi} = 1/3 N_{39}$ , and so on. The first sign of the latter units,  $N_{34}$ ,

Figure 4: TODO [Eng98, p. 113]

For instance, the first line contains the notations  $1N_{34} 1N_{390}; 2N_{20}$ , which can be translated "60 of the (grain rations containing)  $\Xi$  (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  $N_{39}$  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 5: TODO [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 ( $\nabla$ ), 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 biga-Zahlen im Hohlmaßsystem, s.u. 7.4).

Figure 6: TODO [Kreg98, p. 303]

The calculations:

Obv. i	1	$60 \times 1/5 \nabla$	( $\Xi$ )	=	$12 \times \nabla$	=	$2 \times \bullet$		
	2	$120 \times 1/10 \nabla$	( $\Xi$ )	=	$12 \times \nabla$	=	$2 \times \bullet$		
	3	$120 \times 1/15 \nabla$	( $\tilde{\Xi}$ )	=	$8 \times \nabla$	=	$1 \times \bullet$	$2 \times \nabla$	
	4	$300 \times 1/20 \nabla$	( $\tilde{\Xi}$ )	=	$15 \times \nabla$	=	$2 \times \bullet$	$3 \times \nabla$	
	5	$600 \times 1/25 \nabla$	( $\tilde{\Xi}$ )	=	$24 \times \nabla$	=	$4 \times \bullet$		
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> )	=	$30 \times \nabla$	=	$5 \times \bullet$	$1 \times \nabla$	$1 \times \nabla$
	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					$1 \times \bullet$	$4 \times \bullet$	$3 \times \nabla$
							$1 \times \bullet$	$1 \times \bullet$	$5 \times \nabla$
							$1 \times \nabla$	$3 \times \bullet$	$2 \times \nabla$
							$1 \times \bullet$	$4 \times \bullet$	$3 \times \nabla$
							$1 \times \nabla$		$1 \times \nabla$
Grand total of groats used:							$1 \times \nabla$	$2 \times \bullet$	$9 \times \bullet$
Grand total of malt used:							$8 \times \bullet$	$4 \times \nabla$	$1 \times \nabla$

Grand total of malt used:  $1N_{47} 4N_{20} 3N_5 1N_{42a}$  (rev. i 3)  $\times 3/5 \approx$

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

Figure 7: TODO [Englund2001]

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

Figure 8: TODO [Chao3, p. 6]

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

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:

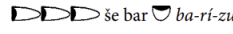
 *še bar ba-rí-zu*  
 ‘3 *gubar* (capacity units) and 1 *parisu*’.

Figure 12: TODO [Cha12, p. 61]











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 13: TODO [Cha12, p. 64]


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*<sup>u</sup>) 3(*u*), means  $2 \times 3600 + 1 \times 600 + 3 \times 10$ ). The system is based on an alternation of factors ten and

Figure 14: TODO





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 15: 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>u9</sup>* 2  4   
 aktum 4  *ib<sub>2</sub><sup>u9</sup>* × 3  *sa<sub>6</sub> gunu<sub>3</sub>*” (Fig. 2).

Figure 16: Transliteration in [Gor23, p. 163] of [P242293, *recto* 4, 1] incorporating untransliterated numerals.



- in personal names in administrative texts, such as the following, which all contain  $\triangleright$  numerals:
  - $\text{𒀭𒀭}$  in [P010424; P010458; P010459] from ED IIIa أبو صلابيخ,
  - $\text{𒀭𒀭}$  in [P010960] from ED IIIa Šuruppag,
  - $\text{𒀭𒀭𒀭𒀭}$  in [P251641] from ED IIIb Adab,
  - $\text{𒀭𒀭𒀭𒀭𒀭𒀭}$  in [P252866] from ED IIIb Adab,
  - $\text{𒀭𒀭𒀭𒀭𒀭𒀭}$  in [P298637] from ED IIIb Umma;
- in the Sumerian word  $\text{𒀭𒀭}$   $\text{u}_2$ -rum, “property” in ED IIIb Nirsu administrative texts which contain  $\triangleright$  numerals, such as [P020006; P020008; P020018; P020024; P020030];
- in lexical texts:
  - in the divine name  $\text{𒀭𒀭𒀭𒀭𒀭𒀭}$  in the lexical texts [P010570; P010572], where the entries are prefixed with  $\triangleright$ .
  - in the word  $\text{𒀭𒀭}$  dili, “small fish” in [P010578], witness to Early Dynastic Fish,
  - in the same word with a determinative,  $\text{𒀭𒀭𒀭}$  dili<sup>ku<sub>6</sub></sup>, in [P010586], witness to Early Dynastic Food, which starts with  $\triangleright$  numerals.

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

### 3.6 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 section 3.1. While these benefits are real and 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  $\text{𒀭𒀭}$  that have both numeric and non-numeric values in both the main list and the section on numbers. For instance, [KWU, pp. 123 sqq.] lists all of  $\text{𒀭𒀭}$  together with  $\triangleright$ - $\text{𒀭𒀭𒀭𒀭}$ , while  $\text{𒀭𒀭}$ ,  $\text{𒀭𒀭}$ , and  $\text{𒀭𒀭}$ , and only those, appear at the beginning of the sign list, since they have non-numeric values<sup>61</sup>. [PTACE, p. 58] has the numeric signs  $\triangleright$ ,  $\text{𒀭𒀭}$ ,  $\text{𒀭𒀭}$ , whereas non-numeric  $\text{𒀭𒀭}$  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, [LAK] writes *s. die Zahlz.* throughout the main list; LAK 1  $\text{𒀭𒀭}$  thus reappears at LAK 829 together with  $\triangleright$ ,  $\text{𒀭𒀭}$ , and  $\text{𒀭𒀭}$ . One should note [MZL], 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  $\text{𒀭𒀭}$ - $\text{𒀭𒀭}$  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>62</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  $\text{𒀭𒀭}$  numerals

<sup>61</sup>Non-numeric values of  $\text{𒀭𒀭}$  were discussed in section 3.5;  $\text{𒀭𒀭}$  has the values *man<sub>3</sub>* and *min<sub>5</sub>*, and is used for the word *didli*, “several, various”;  $\text{𒀭𒀭}$  has the value *eš<sub>6</sub>*.

<sup>62</sup>TODO comment on the ED witnesses to the instructions of Šuruppag

prevents diachronic encoding even if  $\triangleright$  were unified with  $\blacktriangleright$ . For instance, the lexical list Early Dynastic Food, already mentioned in section 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  $\uparrow$  numerals, whereas they are written with  $\triangleright$  numerals in the Early Dynastic witnesses; since  $\uparrow$  and  $\blacktriangleright$  are distinct<sup>63</sup> characters, the  $\triangleright$ - $\blacktriangleright$  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>64</sup>, there is little opportunity for a diachronic representation of numeric quantities.

In the case of analyses such as [Romach2023], it is interesting to note that numeric expressions are removed prior to the conversion of the corpus to Unicode cuneiform for further analysis.

### 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>65</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  $\bullet$  CUNEIFORM SIGN SHAR2 has a circular reference glyph.

In most texts from the Early Dynastic IIIb and Old Akkadian period<sup>66</sup>, a contrast between non-numeric šar<sub>2</sub> written  $\diamond$  and numeric 1(šar<sub>2</sub>) written  $\bullet$  can be observed, similar to the contrast between  $\blacktriangleright$  and  $\triangleright$  previously discussed in section 3.5. However, in lexical lists from Šuruppag and Ebla<sup>67</sup>, as well as in the *Stèle des vautours*, non-numeric šar<sub>2</sub> is curviform:

- $\ast \text{𒌦} \text{𒌦} \bullet$  and  $\ast \text{𒌦} \bullet \text{𒌦} \text{𒌦}$  in [P010566];
- $\bullet \text{𒌦} \text{𒌦}$  and  $\ast \bullet \text{𒌦} \text{𒌦}$  in [P010576];
- $\bullet \text{𒌦}$  in [P240986]<sup>68</sup>;

<sup>63</sup>Besides the contrasts in numeric usage mentioned in section 3.3.3, these characters are clearly not unifiable because of the many contrasts in non-numeric usage between them; several values of  $\blacktriangleright$  which are not shared with  $\uparrow$  have already been mentioned, but perhaps most striking is the fact that, in the Neo-Assyrian period,  $\blacktriangleright$  is used for the preposition *ina*, “in”, and  $\uparrow$  for the preposition *ana*, “to”.

<sup>64</sup>TODO cite a few things here.

<sup>65</sup>Most prominently Noto Sans Cuneiform, a system font on both Windows—as part of Segoe UI Historic—and macOS.

<sup>66</sup>For example, in personal names:

- $\text{𒌦} \text{𒌦} \text{𒌦} \text{𒌦}$  in [P020019] from ED IIIb Nirsu;
- $\text{𒌦} \text{𒌦} \text{𒌦} \text{𒌦}$  in [P020182], also from ED IIIb Nirsu;
- $\text{𒌦} \text{𒌦} \text{𒌦}$  in [P222186] from ED IIIb Umma;
- $\text{𒌦} \text{𒌦} \text{𒌦}$  in [P235312] from Old Akkadian Umma.

<sup>67</sup>TODO Mention other ways in which these are archaizing

<sup>68</sup>From copy in [ELLes, No. 397].

— ● 𐎶𐎵 in [P222399, obv. 17, 9, 18, 11, 22, 12]<sup>69</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 SHAR2 should therefore be used in those cases, with its curviform glyph 𐎶, 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 𐎶 in the relevant metrological systems, there is no need to represent a 𐎶-● contrast, so these characters can have the same glyph in specialist archaizing Early Dynastic fonts.

Since cuneiform U+122B9 CUNEIFORM SIGN SHAR2 effectively merges with U+1212D 𐎶 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.

Note that in rare cases, such as [P222243] from ED IIIa Adab, non-numeric — (here with the value rum) is written 𐎶. It is out of scope for this proposal to decide whether such occurrences should be treated as anomalous spellings, encoded as U+12550 𐎶 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 — 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 𐎶𐎶𐎶𐎶 NE×KASKAL or 𐎶𐎶𐎶𐎶 NE×PAP<sup>70</sup>, they are typically all transliterated bil<sub>2</sub>, and therefore are all represented by the character U+1224B 𐎶 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, 𐎶𐎶𐎶𐎶 from [P305639] 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 𐎶𐎶𐎶𐎶 𐎶𐎶𐎶𐎶 𐎶𐎶𐎶𐎶 𐎶𐎶𐎶𐎶 𐎶𐎶𐎶𐎶 𐎶𐎶𐎶𐎶 𐎶𐎶𐎶𐎶 𐎶𐎶𐎶𐎶 𐎶𐎶𐎶𐎶 𐎶𐎶𐎶𐎶 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>71</sup> za”, reading both 𐎶 and 𐎶 as 1/2, but not distinguishing them.


In particular, these transliterations do not differentiate between — and 𐎶 numerals, nor between 𐎶 and 𐎶 numerals. For instance, the aforementioned 𐎶𐎶𐎶𐎶 𐎶𐎶𐎶𐎶 𐎶𐎶𐎶𐎶 𐎶𐎶𐎶𐎶 𐎶𐎶𐎶𐎶 𐎶𐎶𐎶𐎶 𐎶𐎶𐎶𐎶 𐎶𐎶𐎶𐎶 𐎶𐎶𐎶𐎶 𐎶𐎶𐎶𐎶


<sup>69</sup>Note however 𐎶𐎶𐎶 𐎶𐎶𐎶 on [P222399, obv. 6, 17]. 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. TODO add a photo.

<sup>70</sup>As on [P249253].

<sup>71</sup>As of this writing, EbDA actually has an-zam<sub>x</sub>, with U+1D6A GREEK SUBSCRIPT SMALL LETTER CHI.








but  would be “one slave”.




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 millenium corpora. The oddity of  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 millenium 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 millenium 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 KAŠa, KAŠb, and KAŠc, depicting filled jars with a spout (a), a handle (c), or neither (b), being understood as referring to containers of different substances, see [Englund2001]. 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 script.



As part of the development of these conventions, a classification of fourth millenium 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 ,  $N_{14}$  is ,  $N_{34}$  is , etc. Transliterations of numeric expression then use those to identify the type of number used, thus  $5N_1$  is , and  $5N_{14}$  is .

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] 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 millenium 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.

While the non-numeric signs are treated as undeciphered, the metrological systems used in the fourth millenium 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 section 3.7.2; they are indeed used interchangeably, as in [P011104] which uses the notation u@f in [ePSD2], but  $N_{14}$ @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 millenium would therefore induce confusion as to which numerals should be used in third millenium

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 millenium 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  $\ominus N_{29a}$  is still unknown, but their values are found in [Englund2004] to be  $\frac{1}{10} \ominus$ , whereas  $\frac{1}{6} \ominus$ .

## 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).]

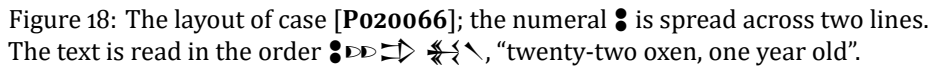
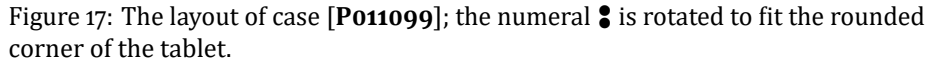
## 6 Characters not included in this proposal

### 6.1 Missing numerals

TODO N13 not attested in CDLI TODO ( $N_{17}$  not usefully numeric,  $12N_{14}$  not encodable, etc.). Cite [DE87, p. 147] 7 and 8(diš *tenû*) encodable, but not today; want to go into the Cuneiform Numbers and Punctuation block for sanity.

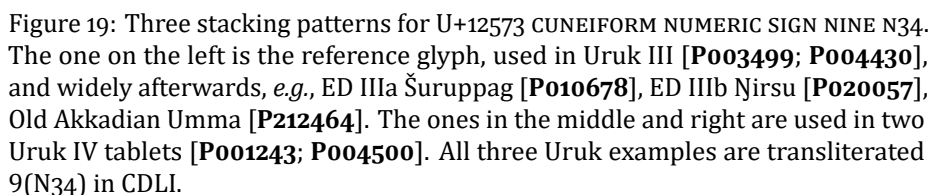
### 6.2 Stacking patterns

The already-encoded numerals in the Cuneiform Numbers and Punctuation block distinguish some *stacking patterns*; for instance 9| 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| is written , as in [P255010; P292843]. Another contrast is that between the stacking patterns used in scratch calculations in the SPVS, often                                         



Likewise, many stacking patterns are attested for the curviform numerals proposed in this document, and it is not proposed to separately encode them; these distinctions would be incompatible with the state of the art in numeric transliterations, and are not needed to represent reference works. Idiosyncratic stacking patterns are in fact particularly common in Early Dynastic and earlier tablets, as they are structured in rectangular cases rather than lines, so that numerals may be laid out across the case in whichever way fits the available space; this is illustrated in Figure 17. Note also that the numerals need to be considerably enlarged in order to reproduce the layout of the tablets, so that 𐎶 often spans two lines of cuneiform signs, as shown in Figure 18. This is impractical when these numerals are set in text that contrasts them with the larger 𐎵, and inconsistent with actual practice when typesetting these numerals, as illustrated in Figure 3: reproducing the layout of tablets is not within the scope of plain text.

The reference glyphs use stacking patterns that are common in the Early Dynastic period, but that are also attested in the Uruk period; the Uruk period also frequently features numerals that use a more vertical layout, as illustrated in Figure 19. The later, more horizontal styles were chosen for two reasons: for the numerals used in the third and fourth millenium, usage in third millenium 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  $\triangleright$ ,  $\triangleright$ ,  $\bullet$ , and  $\bullet$  must remain consistent across the numeral series, lest a  $\triangleright$  numeral be confused with an  $\triangleright$  numeral. Since the single indents are frequently used in running text, as illustrated in section 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 19 uses OpenType stylistic alternates, and Figure 17 rotates the character  $\bullet$ , 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 [Englund2001].

## Acknowledgements

TODO(egg): Something about the Vanséveren fonts

## References

### Artefacts

- [P020054] VAT 4731. [För16, 40 p.14]. Vorderasiatisches Museum.  
CDLI: [P020054](#).
- [P020129] VAT 04713. Vorderasiatisches Museum.  
CDLI: [P020129](#).  
ORACC: [epsd2/corpus/P020129](#).
- [P102305] X.3.139. Michael C. Carlos Museum, Emory University.  
CDLI: [P102305](#).
- [P215653] AS 15375 21. Musée du Louvre.  
CDLI: [P215653](#).  
ORACC: [dcclt/corpus/P215653](#).  
Louvre Collections: [ark:/53355/cl010436723](#).
- [P221266] AO 13825. Musée du Louvre.  
CDLI: [P221266](#).  
ORACC: [epsd2/corpus/P221266](#).  
Louvre Collections: [ark:/53355/cl010138527](#).
- [P221291] AO 13850. Musée du Louvre.  
CDLI: [P221291](#).  
ORACC: [epsd2/corpus/P221291](#).
- [P221305] AO 13864. Musée du Louvre.  
CDLI: [P221305](#).  
ORACC: [epsd2/corpus/P221305](#).
- [P222399] *Stèle des vautours*. AO 50; AO 2346; AO 2347; AO 2348; AO 16109. Musée du Louvre.  
CDLI: [P222399](#).



- [P232278] *Gudea E.* AO 6. Musée du Louvre.  
CDLI: [P232278](#).  
ORACC: [etc/sri/Q001544](#).
- [P232280] *Gudea G.* AO 7. Musée du Louvre.  
CDLI: [P232280](#).  
ORACC: [etc/sri/Q001546](#).
- [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](#).
- [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](#).
- [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](#).  
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