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H.J.J. TE RIELE

FURTHER RESULTS ON UNITARY ALIQUOT SEQUENCES

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FURTHER RESULTS ON UNITARY ALIQUOT SEQUENCES

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TABLES

Further results on unitary aliquot sequences

by

Herman J.J. te Riele.

0. Summary

In this report the study of the behaviour of unitary aliquot sequences, started in "Unitary aliquot sequences" (MR 139/72), is extended. For reasons of comparison, several results of MR 139/72 are included. From the computations of all unitary aliquot sequences with starting values in the intervals $(0, 10^5]$ and $(10^6, 10^6 + 10^3]$ we conclude that these sequences behave in a stable manner; about 88.6% of the sequences are terminating, the others are periodic (except only one sequence with unknown behaviour).

An important part of this study is devoted to the construction of unitary 2-cycles (or unitary amicable pairs). Sections 3 and 4 contain information about 1079 new unitary 2-cycles. In section 5 we list all known other cycles (for $t \neq 2$), including several new cycles. The number of unitary t-cycles now known is 5 for $t = 1$ (discovered by Subbarao and Wall), 1186 for $t = 2$ (107 discovered by Peter Hagis, Jr), 1 for $t = 3$, 8 for $t = 4$, 1 each for $t = 5$ and $t = 6$, 3 for $t = 14$ and 1 for $t = 25$.

In the Appendix, three theorems are given, which deal with the number of different prime factors of the elements of a unitary t-cycle. This appendix is essentially due to Walter Borho.

All computations were carried out on the EL-X8 computer of the Mathematical Centre. Computer time used was about ten hours.

1. Introduction

A divisor d of a natural number n is called unitary, if $(d, n/d) = 1$. If the prime factorization of n is given by

$$n = q_1^{\alpha_1} q_2^{\alpha_2} \dots q_r^{\alpha_r},$$

where $q_1, q_2, \dots, q_r$ are distinct primes, $q_1 < q_2 < \dots < q_r$, and α_i are natural numbers ($i = 1, 2, \dots, r$), then the unitary divisors of n are

$$1, q_1^{\alpha_1}, q_2^{\alpha_2}, \dots, q_r^{\alpha_r}, q_1^{\alpha_1} q_2^{\alpha_2}, q_1^{\alpha_1} q_3^{\alpha_3}, \dots,$$
$$q_{r-1}^{\alpha_{r-1}} q_r^{\alpha_r}, \dots, q_1^{\alpha_1} q_2^{\alpha_2} \dots q_r^{\alpha_r},$$

and their sum $\sigma^*(n)$ can be written as

$$\sigma^*(n) = (q_1^{\alpha_1} + 1)(q_2^{\alpha_2} + 1) \dots (q_r^{\alpha_r} + 1).$$

The function $s^*(n) = \sigma^*(n) - n$ is called the sum of the unitary aliquot divisors of n. We define $s^*(1) = s^*(0) = 0$.

A unitary aliquot sequence of n (abbreviated: UAS of n) is a sequence (n_i), defined by

$$n_0 = n,\ n_1 = s^*(n_0),\ \dots,\ n_i = s^*(n_{i-1}),\ \dots\ .$$

Examples

1.1	UAS of 80:	80, 22, 14, 10, 8, 1, 0, 0, ...
1.2	UAS of 220:	220, 140, 100, 30, 42, 54, 30, ...
1.3	UAS of 3672:	3672, 864, 60, 60, ...
1.4	UAS of 1482:	1482, 1878, 1890, 2142, 2178, 1482, ...
1.5	UAS of 89610:	89610, 135010, 235914, 320502, 469770, 819318, ...

Sometimes, the (i+1)th term n_i of a UAS of n_0 is denoted by $n_0 : i$, for instance $80 : 5 = 1$, $220 : 3 = 30$, $220 : 6 = 30$, $1482 : 5 = 1482$.

A t-tuple of distinct numbers $(n_0, n_1, \dots, n_{t-1})$ with

$$n_i = s^*(n_{i-1})\ (i = 1, 2, \dots, t-1) \text{ and } s^*(n_{t-1}) = n_0,$$

will be called a unitary t-cycle[+]; unitary 1-cycles are also called unitary perfect numbers [7], unitary 2-cycles are also unitary amicable pairs [3].

According to their behaviour, unitary aliquot sequences can be divided into three classes:

(i) Some term n_j of the sequence is a prime number, or a prime power; then the next term n_{j+1} equals 1 and $n_i = 0$ for $i > j + 1$. This UAS is called terminating. The index l such that $n_l = 1$ is called the length of the sequence; thus the length of the UAS of 80 is 5 (see 1.1).

(ii) A UAS is called periodic, if there exists an index k such that the t-tuple $(n_k, n_{k+1}, \ldots, n_{k+t-1})$ is a unitary t-cycle. The least index k such that n_k is a member of a unitary t-cycle is called the preperiod l' and $n_{l'}$ the endpoint of the periodic UAS. If $l' = 0$, then we have a purely periodic sequence, else ($l' > 0$) an ultimately periodic sequence.

For instance,

UAS of 220, $l' = 3$, $t = 3$, ultimately periodic (see 1.2);

UAS of 3672, $l' = 2$, $t = 1$, ultimately periodic (see 1.3);

UAS of 1482, $l' = 0$, $t = 5$, purely periodic (see 1.4).

(iii) The UAS is unbounded. It is not known, whether unbounded unitary aliquot sequences do exist. During our computations (including those in [6]) we only met one UAS, the terms of which became too large for our computational means. 11409 of the remaining 99999 sequences are periodic, the other 88590 sequences are terminating. In [6] we have proved the existence of UAS-s with m monotonically increasing terms, for any given natural number m, but this does not prove the existence of unbounded UAS-s.

[+] In [6] we proposed the name "unitary sociable group of order t",but this name suggests other mathematical concepts than we mean.

2. Unitary aliquot sequences with starting value less than 100000

The computations in [6] have now been extended to all UAS-s with starting values less than 100000 (was 40000). Only one sequence with unknown behaviour was left.

This sequence starts with $n_0 = 89610$; we stopped after the computation of

$$89610 : 541 = 114601234388928504726 = 2.3.c,$$

where c is a composite number.

Many results of our computations have been collected in tables 1, 2, 3, 4 and 10. We have included some results from [6], for purposes of comparison.

Table 1 shows the distribution of all UAS-s with starting values less than 100000 among classes (i) and (ii), for intervals of length 10000. Of all these sequences, those, with an odd starting value are terminating.[+] In general, the length of these sequences is small, compared with the length of terminating sequences with an even starting value. An explanation of this phenomenon is given by the following two observations:

- We can distinguish between odd and even unitary aliquot sequences. Indeed, if n is odd, then $s^*(n)$ is odd, and if n is even, then $s^*(n)$ is even or equals 1.
- The average value of $\frac{s^*(n)}{n}$ equals .3684 (see [6]), while the contribution of the odd natural numbers to this value is .0865 and of the even natural numbers .2819.

Some information about the only UAS with unknown behaviour can be found in Table 2. The first 21 terms of this sequence, and all subsequent terms which have two prime factors greater than 10^6 have been included in this Table, together with their factorizations.

[+] In fact, there are only 34 odd unitary abundant numbers (numbers n such that $s^*(n) / n > 1$) less than 10^5, and a unitary cycle must contain such a number.

TABLE 1 Behaviour of all unitary aliquot sequences with starting value $\leqq$ 100000.

	terminating	periodic						unknown
		t=1	t=2	t=3	t=4	t=5	t=14	
(0, 10000]	9025	191	149	472	0	101	62	0
(10000, 20000]	8933	184	261	466	0	136	20	0
(20000, 30000]	8943	179	277	422	0	151	28	0
(30000, 40000]	8800	174	279	520	0	180	47	0
(40000, 50000]	8800	187	304	466	0	206	37	0
(50000, 60000]	8856	141	304	463	0	182	54	0
(60000, 70000]	8783	166	373	491	0	137	50	0
(70000, 80000]	8840	133	349	460	0	178	40	0
(80000, 90000]	8828	165	343	482	1	153	27	1
(90000, 100000]	8782	177	366	480	0	162	33	0
(0 , 100000]	88590	1697	3005	4722	1	1586	398	1
	88.59%	11.41%						0.00%

TABLE 2 A unitary aliquot sequence with unknown behaviour.

k	89610:k	factorization	k	89610:k	factorization
0	89610	2.3.5.29.103			
1	135030	2.3.5.7.643	11	1234518	2.3.61.3373
2	235914	2.3.7.41.137	12	1275738	2.3.149.1427
3	320502	2.3.7.13.587	13	1294662	2.3.47.4591
4	469770	2.3.5.7.2237	14	1350330	2.3.5.19.23.103
5	819318	2.3.19.7187	15	2243910	2.3.5.74797
6	905802	2.3.150967	16	3141546	2.3.293.1787
7	905814	2.3E2.7E2.13.79	17	3166518	2.3.527753
8	774186	2.3.7.18433	18	3166530	2.3.5.59.1789
9	995478	2.3.11.15083	19	4566270	2.3.5.19.8011
10	1176618	2.3.41.4783	20	6971010	2.3.5.232367

k	89610:k	factorization
400	8955713959776978	2.3.3270287.456418349
417	3075877414787366	2.3E2.1097501.1557010687
426	3587172678627613 8	2.3.26278393.227510911
439	39691536251296950	2.3E2.5E2.2416123.36506177
441	34399367297077590	2.3E2.5.23.2615779.6353003
463	40283418787462182	2.3.2651629.2531991893
471	51270385551153126	2.3.1126211.7587445211
474	54859868916679290	2.3.5.113.1202107.13462073
475	77969102204471046	2.3.1297.3000761.3338873
498	141247679903833962	2.3.1794731.13116884917
510	209027463954231162	2.3.109641061.317745107
521	522174191541082186 2	2.3.883.1546403.637354073
524	607603693150750722 6	2.3.31.1301.1946453.12899897
527	1344859193757408279 0	2.3.5.20181463.22212780011
541	1146012343889285047 26	2.3.c

According to Table 1, the total number of periodic UAS-s is 11409. 64 of them are purely periodic, the others ultimately. It is of interest to know, into which unitary t-cycles these sequences lead, and with what frequencies. This is shown in Table 3. The only periodic sequence, which leads into a unitary <u>4-cycle</u>, is the sequence 81570, 114270, 182082, 182094, 232626, 237678, 305682, 352878, 360978, 403662, 420738, <u>420750</u>, 395730, 395910, 420570, <u>420750</u>, ...

Table 4 shows more details of periodic UAS-s with endpoints which are frequently reached, viz., the distribution of the frequencies of the starting values among intervals of length 10000. The frequencies seem to be rather constant (roughly speaking), when we look at different intervals. Another remarkable fact is, that the numbers 30, 42, 54 are reached with frequencies which are in a ratio of (roughly) 3 : 2: 1, while the numbers 114 and 126 are reached with frequencies which have a ratio of about 1 : 1. The number 1140 is 44 times an endpoint of a UAS, whereas 1260 is reached only once (by 1140).

TABLE 3 Unitary t-cycles into which lead the 11409 periodic unitary aliquot sequences with starting values ≤ 100000, and frequencies.

t	unitary t-cycle	freq.	t	unitary t-cycle	freq.	t	unitary t-cycle	freq.
1	6	1	2	44772	2	4	395730	0
1	60	218		49308	2		395910	0
1	90	1477	2	56430	1576		420570	0
1	87360	1		64530	3		420750	1
			2	67158	1			
2	114	579		73962	1	5	1482	1
	126	556	2	1080150	0		1878	35
2	1140	44		1291050	205		1890	134
	1260	1					2142	31
2	18018	32	3	30	2377		2178	1385
	22302	1		42	1525			
2	32130	1		54	820			
	40446	1						

t	unitary t-cycle	freq.	t	unitary t-cycle	freq.	t	unitary t-cycle	freq.
14	2418	136	14	24180	39	14	35238	13
	2958	24		29580	3		45402	1
	3522	13		35220	1		65190	1
	3534	4		35440	1		98106	2
	4146	4		41460	2		101478	0
	4158	17		41580	1		117258	0
	3906	2		39060	1		117270	0
	3774	4		37740	1		117450	0
	4434	2		44340	3		74430	26
	4446	9		44460	2		74610	2
	3954	1		39540	1		74790	1
	3966	18		39660	2		65322	3
	3978	1		39780	2		49878	33
	3582	1		35820	1		38682	20

TABLE 4 Distribution of starting values of the periodic unitary aliquot sequences which end in a member of one of the unitary t-cycles (60), (90), (114, 126), (1140, 1260), (30, 42, 54)

Unitary t-cycle	60	90	114	126	1140	1260	30	42	54
t =	1	1	2		2		3		
Interval									
(0- 10000]	30	160	56	61	8	1	219	163	90
(10000- 20000]	23	161	60	57	5	0	237	156	73
(20000- 30000]	16	163	47	39	4	0	214	136	72
(30000- 40000]	24	150	68	47	3	0	271	157	92
(40000- 50000]	29	158	57	64	4	0	245	140	81
(50000- 60000]	12	129	60	67	2	0	249	141	73
(60000- 70000]	12	154	70	55	2	0	240	169	82
(70000- 80000]	22	111	53	57	7	0	217	164	79
(80000- 90000]	26	138	53	50	2	0	247	158	77
(90000-100000]	24	153	55	59	7	0	238	141	101
(0-100000]	218	1477	579	556	44	1	2377	1525	820

The question arises whether the behaviour of UAS-s, as shown in Table 1, stays the same, when we look at all UAS-s with starting value in the interval (say) (1000000, 1001000]. We have computed these sequences, and the results are laid down in Table 5; for reasons of comparison, we have included in this Table the totals from Table 1. One very long periodic sequence was found, viz., the UAS of 1000830, preperiod l' = 791, endpoint = 2178, period = 5, maximum term = 1000830 : 588 = 1623583833750.

TABLE 5 Behaviour of all unitary aliquot sequences with starting values in the intervals (0, 100000] and (1000000, 1001000].

	terminating	periodic						unknown
		t=1	t=2	t=3	t=4	t=5	t=14	
(0, 100000]	88590	1697	3005	4722	1	1586	398	1
	88.6%	11.4%						0.0%
(1000000, 1001000]	883	14	35	43	0	22	3	0
	88.3%	11.7%						0.0%

In Table 10 (p.37-56) we present more information about the 7110 periodic unitary aliquot sequences with starting values in the interval (40000, 100000], viz., their starting values, the preperiods and the endpoints^{+}. In case of purely periodic UAS-s, only the starting value is given; this value occurs in Table 3 as a member of a unitary t-cycle. 20 sequences are purely periodic; the other 7090 sequences are ultimately periodic. [6] contains a similar Table for the interval (0, 40000].

Conclusions Unitary aliquot sequences seem to behave in a stable manner. About 88.6% are terminating, about 11.4% are periodic. Whether or not unbounded unitary aliquot sequences exist, is an open question, although it is known that arbitrarily long sequences can be constructed. Very long terminating sequences, with more than 1100 terms are known [6]. The longest known periodic sequence has 791 terms before the periodic part.

$^{+}$Table 10 also contains the starting value 89610 of the only sequence with unknown behaviour.

3. Construction of unitary amicable pairs from amicable pairs.

Two theorems from [6] deal with the construction of unitary t-cycles; application of these theorems to the construction of unitary amicable pairs (t=2), yields 1062 new unitary amicable pairs.

The list of nearly all known amicable pairs, recently published by Lee and Madachy [5], is our starting point. When we speak about "the LIST", we mean this list. Moreover, David [1] has recently discovered several new amicable pairs; we shall use some of them, which are suitable for our construction.

Our first tool is the following theorem from [6]; we present it in a form, suitable for our purpose here.

Theorem 3.1 Let (n_1, n_2) be an amicable pair; suppose it is possible to write n_1 and n_2 as

3.1 $$n_1 = a\, m_1,\ n_2 = a\, m_2,$$

where $a > 1$, $(a, m_1) = (a, m_2) = 1$, and m_1 and m_2 are squarefree; if a natural number $b > 1$ exists, such that

3.2 $$\sigma(a) / a = \sigma^*(b) / b,$$

with $(b, m_1) = (b, m_2) = 1$, then the numbers $b\, m_1$ and $b\, m_2$ form a unitary amicable pair.

Examples We take amicable pair no. 6 from the LIST

$$(n_1, n_2) = (2^3 17.79,\ 2^3 23.59);$$

then with $a = 2^3$, $m_1 = 17.79$, $m_2 = 23.59$, condition 3.1 has been satisfied. Now we look for a natural number $b > 1$ such that

$$\sigma^*(b) / b = 15 / 8 = \sigma(a) / a.$$

This number is given by $b = 2^{10} 3.5.7.41$. Since $(b, m_1) = (b, m_2) = 1$, condition 3.2 has also been satisfied. Hence it follows from theorem 3.1 that

$$(2^{10}3.5.7.41.17.79,\ 2^{10}3.5.7.41.23.59)$$

is a unitary amicable pair.
Another example: start with

$$(n_1,\ n_2) = (3^2 5.13.11.19,\ 3^2 5.13.239),$$

amicable pair no. 15 from the LIST. $a = 3^2 5$ ($m_1 = 11.13.19$, $m_2 = 13.239$) satisfies condition 3.1 and if $b = 2^2 3.5^2$, then

$$\sigma^*(b)\ /\ b = 26\ /\ 15 = \sigma(a)\ /\ a,$$

thus condition 3.2 has also been satisfied. Hence

$$(2^2 3.5^2 11.13.19,\ 2^2 3.5^2 13.239)$$

is a unitary amicable pair.

The difficulty in these examples is to find a number b which satisfies 3.2, for a given number a.

If a is squarefree, then $\sigma^*(a)\ /\ a = \sigma(a)\ /\ a$, so that we can take $b = a$; hence the amicable pair itself is a unitary amicable pair. In the LIST we have counted 89, and in David's discoveries, 5 squarefree pairs, a total of 94 squarefree amicable, and thus unitary amicable pairs. Hagis [3] has already mentioned 75 of these squarefree unitary amicable pairs. (Not 76, because, according to Lee and Madachy [5a], the squarefree amicable pair (177) in [4] is actually García's pair (29) on page 169 of [2]).

A computer program traced all pairs (a,b) with $a < 13000$ and $b < 13000$, such that $\sigma(a)\ /\ a = \sigma^*(b)\ /\ b$. Some other suitable pairs (a,b) were found by hand. The results are laid down in Table 6; this table extends Table 9 in [6].

TABLE 6 Numbers a and b, satisfying $\sigma(a) / a = \sigma^*(b) / b$

a	b	$\sigma(a) / a = \sigma^*(b) / b$
2^2	$2^6 3.5.13$	7/4
2^3	$2^{10} 3.5.7.41$	15/8
3^2	$2^2 3^2 5^2$	13/9
$3^2 5$	$2^2 3.5^2$	26/15
$3^2 13$	2.3^3	14/9
3^3	$2^2 3^3 7$	40/27
$3^3 5$, $3^2 7.13$	$2.3^3 7$	16/9
$3^3 5^3$, $3^2 5^2 31$	$2.3^3 5^2 7$	416/225
$5^2 31$	$5^2 7.13$	32/25
$5^3 13$	3.5^3	168/125
$7^2 19$	5.7^2	60/49
$3^2 7^2 13.19$	$2^2 3.7$	40/21

<u>Remark</u> The pairs $a = 3^3 5$, $b = 2.3^3 7$ and $\bar{a} = 3^3 5^3$, $\bar{b} = 2.3^3 5^2 7$ are related by the following property: If a and b satisfy $\sigma(a) / a = \sigma^*(b) / b$, and if $p^k \parallel a$ ($k \geq 1$, p prime) and $p \nmid b$, then the numbers $\bar{a} = a\, p^{k+1}$ and $\bar{b} = b.p^{k+1}$ also satisfy this equation. The proof of this simple property depends on the relation $\sigma(p^{2k+1}) = \sigma(p^k)\, \sigma^*(p^{k+1})$ ($k \geq 1$). With this property, other pairs $(\bar{a},\bar{b})$, satisfying $\sigma(\bar{a}) / \bar{a} = \sigma^*(\bar{b}) / \bar{b}$, can be constructed from pairs (a,b) of Table 6. However, we didn't meet amicable pairs with such an $\bar{a}$ as common factor; therefore those pairs $(\bar{a},\bar{b})$ have been omitted from Table 6.

The LIST contains 1095 amicable pairs (without those in the APPENDIX); we could construct a unitary amicable pair from 361 of them, by use of Theorem 3.1 and Table 6. Theorem 3.1 could also be applied to ten of David's amicable pairs, giving a total of 371 unitary amicable pairs, constructed with Theorem 3.1.

Our second tool for the construction of unitary amicable pairs is the following theorem, taken from [6], in a form suitable for our purpose here;

this theorem enables us to construct unitary amicable pairs from other, given, unitary amicable pairs, and will be applied to the 371 pairs, constructed with Theorem 3.1.

Theorem 3.2 Let (n_1, n_2) be a unitary amicable pair; suppose it is possible to write n_1 and n_2 as

3.3 $$n_1 = a\, m_1,\ n_2 = a\, m_2,$$

where $a > 1$, $(a, m_1) = (a, m_2) = 1$; if a natural number $b > 1$ exists, such that

3.4 $$\sigma^*(a) / a = \sigma^*(b) / b,$$

with $(b, m_1) = (b, m_2) = 1$, then the numbers $b\, m_1$ and $b\, m_2$ also form a unitary amicable pair.

Remark 1 In analogy with the so called "isotopic" or "isomeric" amicable pairs [5a], the two unitary amicable pairs, occurring in Theorem 3.2 might also be called "isotopic" or "isomeric".

Remark 2 In contrast with Theorem 3.1, Theorem 3.2 does not require m_1 and m_2 to be squarefree.

Example Let us consider the unitary amicable pair

$$(2^2 3.5^2 13.11.19,\ 2^2 3.5^2 13.239),$$

constructed in the second example of Theorem 3.1. $a = 2^2 3.5^2 13$ satisfies condition 3.3 and $b = 2.3^3 5$ satisfies condition 3.4 $\sigma^*(b) / b = 28/15 = \sigma^*(a) / a$; hence it follows from Theorem 3.2 that

$$(2.3^3 5.11.19,\ 2.3^3 5.239)$$

is also a unitary amicable pair.

Again, the difficulty is to find numbers b, which satisfy condition 3.4, for given a. Table 7 lists the pairs (a,b) satisfying condition 3.4; several were found by systematic computer search, some by hand. Table 7 is an extension of the second part of Table 8 in [6].

TABLE 7 Numbers a and b, satisfying $\sigma^*(a) / a = \sigma^*(b) / b$

a	b	$\sigma^*(a) / a = \sigma^*(b) / b$
2	$2^2 5, 2^3 3$	3/2
2^2	$2^3 3^2, 2^6 7.13$	5/4
2^3	$2^4 17, 2^5 11$	9/8
2^5	$2^7 43$	33/32
2^7	$2^8 257$	129/128
2^9	$2^{11} 683$	513/512
2^{11}	$2^{13} 2731$	2049/2048
2^{15}	$2^{16} 65537$, $2^{17} 43691$	32769/32768
2.3^3	$2^2 3^2 5^2 13$	14/9
$2.3^3 5$	$2^2 3.5^2 13$	28/15
$2^2 3$	2.3^2	5/3
$2^3 3^3 5$	$2^2 5^2 13$	7/5
$2^4 5.7.13$	$2.5^2 13^2$	102/65
3	$3^2 5$, $2^3 3^3 7$	4/3
3.5	$2^2 5^2 7.13$	8/5
$3^2 7$	$3^3 5.7^2$	80/63
3^3	$3^4 41$	28/27
5.7	$3.5^3 7^2$	48/35
$5^2 13$	$3^2 5^3$	28/25
7	$5^2 7^2 13$	8/7
11	$2^5 11^2 31.61$	12/11

Remark Several pairs (a,b), satisfying condition 3.4 can be found with one of the following three rules [6]:

(i) If $2^{\alpha+1} + 1$ ($\alpha \geq 1$) is a prime or a prime power, then the pair $a = 2^\alpha$, $b = 2^{\alpha+1} (2^{\alpha+1} + 1)$ satisfies 3.4.

(ii) If $(2^{\beta+2} + 1) / 3$ ($\beta \geq 1$) is a prime or a prime power, then the pair $a = 2^\beta$, $b = 2^{\beta+2} (2^{\beta+2} + 1) / 3$ satisfies 3.4.

(iii) If $(3^{\gamma+1} + 1) / 2$ $(\gamma \geq 1)$ is a prime or a prime power, then the pair $a = 3^{\gamma}$, $b = 3^{\gamma+1} (3^{\gamma+1} + 1) / 2$ satisfies 3.4.

Rules (i) and (iii) suggest the question: do the numbers $a = p^{\alpha}$, $b = p^{\alpha+1}$ q, where p is a prime and q is a prime or a prime power, satisfy 3.4 for other values than p = 2 and p = 3? The answer is no. Indeed, if a and b satisfy 3.4, then

$$q = (p^{\alpha+1} + 1)\ (p - 1) = p^{\alpha} + p^{\alpha-1} + \ldots + p + 1 + 2 / (p - 1);$$

hence q can only be an integer if p = 2 or p = 3.

Application of Theorem 3.2, with help of Table 7, to the 371 unitary amicable pairs constructed with Theorem 3.1, yielded 785 other pairs, making a total of 1156. 94 of these have been found by Hagis, Jr. [3], the other 1062 seem to be new.

Information about these 1156 unitary amicable pairs can be found in Tables 8 and 9 (pp. 24-35 and p. 36).

Description of Tables 8 and 9

Table 8 lists the 371 unitary amicable pairs constructed with Theorem 3.1, together with the number of isotopic pairs found with Theorem 3.2. The greatest common divisor of the unitary amicable pair has been placed in column 1 of Table 8 (exponents are in linear form: 2^3 is written as 2E3), the remaining parts are in column 2. Column 3 gives the reference of the amicable pair, from which the unitary amicable pair has been constructed, viz., the no. in the LIST, or David [1]. In case of isotopic amicable pairs, two no.'s (one between brackets) are given in this column; both amicable pairs, of course, yield the same unitary amicable pair. Finally, column 4 tells how many unitary amicable pairs, isotopic with the pair in columns 1 and 2, have been constructed with Theorem 3.2. Pairs found by Hagis, Jr. [3] have been marked by the letter H. One letter H in column 4 means one pair from Hagis, Jr; this pair is explicitly given in [3].

The reader can find the isotopic pairs as follows. Take the part of the g.c.d. that stands to the left of the letter a. Call this number a and trace this number in column a of Table 9. The numbers b such that $\sigma^*(b) / b = \sigma^*(a) / a$ can be read from column b of Table 9. Sometimes, not all given values of b can be used, because of one or more "disturbing" factors in the unitary amicable pair (factors such that the condition $(b, m_1) = (b, m_2) = 1$ of Theorem 3.2 cannot be satisfied). These disturbing factors have been underlined in Table 8. In a few cases, special disturbing factors always occur in unitary amicable pairs with the same a. These factors are also explicitly given in Table 9.

Table 8 has been divided into two parts. PART 1 deals with unitary amicable pairs, "constructed" from squarefree amicable pairs, PART 2 with those, constructed from non-squarefree amicable pairs. In PART 2, the g.c.d. of the original amicable pair has a place in column 1, between brackets.

Examples of Table 8.

	column 1	column 2	column 3	column 4
	g.c.d.	remaining parts	from no. in [5]	number of isotopic un.am. pairs, found with Th.3.2
(i)	2.5a	7.107.719,17.179.191 H	79	4
(ii)	2.7a19.61.853	11.3889679,17.37.68239 H	989	7 H
(iii)	2E10.3.5.7.41 (2E3)	17.79,23.59	6	0
(iv)	2.3E3.7a11 (3E3.5.11)	23.659,79.197	149(254)	4

(i) Unitary amicable pair (2.5.7.107.719, 2.5.17.179.191), found by Hagis, Jr.; the amicable pair is no. 79 in the LIST. Four "isotopic" unitary amicable pairs were found. Indeed, for a = 2.5, Table 9 shows five possible values of b such that $\sigma^*(b) / b = \sigma^*(a) / a$.

a	b
2.5	2E3.3.5
	2E4.3.5.17
	2E5.3.5.11
	2E7.3.5.11.43
	2E8.3.5.11.43.257,

but the second value of b is impossible, because of the disturbing factor 17.

(ii) Unitary amicable pair (2.7.19.61.853.11.3889679, 2.7.19.61.853.17.37.68239), indicated by Hagis, Jr.; the amicable pair is no. 989 in the LIST. Seven isotopic unitary amicable pairs could be found with Theorem 3.2. One of them comes from Hagis, Jr. For a = 2.7, with disturbing factors 11 and 17, Table 9 shows 7 possible values of b.

(iii) Unitary amicable pair ($2^{10}3.5.7.41.17.79$, $2^{10}3.5.7.41.23.59$), found with Theorem 3.1; the amicable pair is no. 6 ($2^{3}17.79$, $2^{3}23.59$) in the LIST. No isotopic unitary amicable pairs were found.

(iv) Unitary amicable pair ($2.3^{3}7.11.23.659$, $2.3^{3}7.11.79.197$), found with Theorem 3.1; the amicable pair is no. 149 ($3^{3}5.11.23.659$, $3^{3}5.11.79.197$) in the LIST, no. 254 in the LIST is "isotopic" with this pair.

Four isotopic unitary amicable pairs were found with Theorem 3.2; indeed, for a = $2.3^{3}7$, Table 9 gives four values of b, satisfying

$\sigma^{*}(b) / b = \sigma^{*}(a) / a$.

4. Other unitary amicable pairs

In section 3 we have studied unitary amicable pairs, "generated" by ordinary amicable pairs, i.e. unitary amicable pairs which are connected with amicable pairs by Theorem 3.1. Only a part (about one third) of the known amicable pairs generates unitary amicable pairs. The other two thirds of the known amicable pairs seem to be "isolated" from the collection of unitary amicable pairs. For some amicable pairs, this is clear, viz., for "exotic" amicable pairs. Lee & Madachy [5a] define exotic pairs as (we cite) "pairs which satisfy one or both of the following conditions.
a) The quotient of at least one member of the pair by the greatest common divisor of the pair is not relatively prime to the greatest common divisor;
b) the quotient of at least one member of the pair by the greatest common divisor of the pair is not square-free". Now let $(a\ m_1,\ a\ m_2)$ be an exotic amicable pair (a is the g.c.d.); then theorem 3.1 cannot be applied to this pair because a) implies that $(a,\ m_1) \neq 1$ or $(a,\ m_2) \neq 1$, while b) implies that at least one of m_1 and m_2 is not squarefree. Thus the collection of exotic amicable pairs <u>is</u> isolated from the collection of unitary amicable pairs. Several non-exotic amicable pairs remain, from which I have not been able to construct unitary amicable pairs. I call these amicable pairs "maybe-isolated".

A close look at Theorem 3.1 reveals that it is easy to prove the converse theorem: if $(n_1,\ n_2)$ is a unitary amicable pair, and if n_1 and n_2 can be written as $n_1 = a\ m_1$, $n_2 = a\ m_2$, where $a > 1$, $(a,\ m_1) = (a,\ m_2) = 1$ and m_1 and m_2 are squarefree, then the existence of a number $b > 1$ such that $(b,\ m_1) = (b,\ m_2) = 1$, and $\sigma(b)\ /\ b = \sigma^*(a)\ /\ a$, implies that the pair $(b\ m_1,\ b\ m_2)$ is an amicable pair.

All unitary amicable pairs, obtained in section 3 are thus connected with the collection of amicable pairs by this theorem. However, also isolated (exotic) and maybe-isolated unitary amicable pairs are known. We list them here. Those found by Hagis, Jr. are marked with the letter H.

Maybe-isolated unitary amicable pairs

H $2^2 3.7 \begin{cases} 13.41 \\ 587 \end{cases}$ Also: $2^2 3.7$ replaced by H $2.3^2 7$, H $2^2 3^2 5.7$, $2.3^3 5.7^2$.

H $2^2 3.7 \begin{cases} 13.719 \\ 59.167 \end{cases}$ Also: $2^2 3.7$ replaced by H $2.3^2 7$, $2^2 3^2 5.7$, $2.3^3 5.7^2$, $2.3^4 5.7^2 41$

Isolated (exotic) unitary amicable pairs

H $2 \begin{cases} 3.19 \\ 3^2 7 \end{cases}$ Also: 2 replaced by H $2^2 5$

H $2.7 \begin{cases} 3^2 11.13 \\ 3^3 59 \end{cases}$ Also: 2.7 replaced by H $2^2 5.7$

H $2^2 3 \begin{cases} 5.11.13.23 \\ 5^3 191 \end{cases}$ Also: $2^2 3$ replaced by H 2.3^2

H $2^2 3 \begin{cases} 5.11.467 \\ 5^2 23.53 \end{cases}$ Also: $2^2 3$ replaced by H 2.3^2 and $2^6 3.7.13$

$2^2 3 \begin{cases} 5.13.31.53 \\ 5^3 23.47 \end{cases}$ Also: $2^2 3$ replaced by 2.3^2

$2^2 3 \begin{cases} 5.13.97.107 \\ 5^3 11.587 \end{cases}$ Also: $2^2 3$ replaced by 2.3^2

$2^2 3 \begin{cases} 5.17.1871 \\ 5^2 11.647 \end{cases}$ Also: $2^2 3$ replaced by 2.3^2 and $2^6 3.7.13$

$2^2 3 \begin{cases} 5.127.701 \\ 5^2 7.2591 \end{cases}$ Also: $2^2 3$ replaced by 2.3^2

$2^2 3 \begin{cases} 5.127.1871 \\ 5^2 11.23.191 \end{cases}$ Also: $2^2 3$ replaced by 2.3^2 and $2^6 3.7.13$

5. Unitary t-cycles for $t \neq 2$.

In this section we present a list of all known unitary t-cycles for $t \neq 2$[+], viz. 5 for t = 1, 1 for t = 3, 8 for t = 4, 1 for t = 5, 1 for t = 6, 3 for t = 14 and 1 for t = 25. Those, marked with the letter N are new.

t = 1

6(2.3) $60(2^2 3.5)$ $90(2.3^2 5)$ (Subbarao & Warren)
$87360(2^6 3.5.7.13)$ (Subbarao & Warren)
$146361946186458562560000(2^{18} 3.5^4 7.11.13.19.37.79.109.157.313)$ (Wall)

t = 3

30(2.3.5) [6]
42(2.3.7)
$54(2.3^3)$

t = 4

$263820(2^2 3.5.4397)$N $395730(2.3^2 5.4397)$N
$263940(2^2 3.5.53.83)$ $395910(2.3^2 5.53.83)$
$280380(2^2 3.5.4673)$ $420570(2.3^2 5.4673)$
$280500(2^2 3.5^3 11.17)$ $420750(2.3^2 5^3 11.17)$

$384121920(2^6 3.7.13.5.4397)$N
$384296640(2^6 3.7.13.5.53.83)$
$408233280(2^6 3.7.13.5.4673)$
$408408000(2^6 3.7.13.5^3 11.17)$

209524210(2.5.7.19.263.599) (David)
246667790(2.5.17.59.24593)
231439570(2.5.19.23.211.251)
230143790(2.5.17.499.2713)

$2514290520(2^3 3.5.7.19.263.599)$ [6]
$2960013480(2^3 3.5.17.59.24593)$
$2777274840(2^3 3.5.19.23.211.251)$
$2761725480(2^3 3.5.17.499.2713)$

$110628782880(2^5 3.5.11.7.19.263.599)$ [6]
$130240593120(2^5 3.5.11.17.59.24593)$
$122200092960(2^5 3.5.11.19.23.211.251)$
$121515921120(2^5 3.5.11.17.499.2713)$

[+] A list of all unitary 2-cycles (m, n) with min $(m, n) < 10^6$, including factorizations, can be found in [3].

19028150655360($2^7 3.5.11.43.7.19.263.599$) [6]
22401382016640($2^7 3.5.11.43.17.59.24593$)
21018415989120($2^7 3.5.11.43.19.23.211.251$)
20900738432640($2^7 3.5.11.43.17.499.2713$)

9780469436855040($2^8 3.5.11.43.257.7.19.263.599$) [6]
11514310356552960($2^8 3.5.11.43.257.17.59.24593$)
10803465818407680($2^8 3.5.11.43.257.19.23.211.251$)
10742979554376960($2^8 3.5.11.43.257.17.499.2713$)

t = 5	1482(2.3.13.19) [6]	t = 6	698130($2.5.3^2 7757$)N
	1878(2.3.313)		698310($2.5.3^2 7759$)
	1890($2.3^3 5.7$)		698490($2.5.3^3 13.199$)
	2142($2.3^2 7.17$)		712710($2.5.3^2 7919$)
	2178($2.3^2 11^2$)		712890($2.5.3^2 89^2$)
			713070($2.5.3^3 19.139$)

t = 14	2418(2.3.13.31) [6]	24180($2^2 5.3.13.31$) [6]	35238(2.3.7.839) [6]
	2958(2.3.17.29)	29580($2^2 5.3.17.29$)	45402(2.3.7.23.47)
	3522(2.3.587)	35220($2^2 5.3.587$)	65190(2.3.5.41.53)
	3534(2.3.19.31)	35340($2^2 5.3.19.31$)	98160(2.3.83.197)
	4146(2.3.691)	41460($2^2 5.3.691$)	101478(2.3.13.1301)
	4158($2.3^3 7.11$)	41580($2^2 5.3^3 7.11$)	117258(2.3.19543)
	3906($2.3^2 7.31$)	39060($2^2 5.3^2 7.31$)	117270($2.3^2 5.1303$)
	3774(2.3.17.37)	37740($2^2 5.3.17.37$)	117450($2.3^4 .5^2 29$)
	4434(2.3.739)	44340($2^2 5.3.739$)	74430($2.3^2 5.827$)
	4446($2.3^2 13.19$)	44460($2^2 5.3^2 13.19$)	74610($2.3^2 5.829$)
	3954(2.3.659)	39540($2^2 5.3.659$)	74790($2.3^3 5.277$)
	3966(2.3.661)	39660($2^2 5.3.661$)	65322($2.3^2 19.191$)
	3978($2.3^2 13.17$)	39780($2^2 5.3^2 13.17$)	49878($2.3^2 17.163$)
	3582($2.3^2 199$)	35820($2^2 5.3^2 199$)	38682($2.3^2 7.307$)

$\underline{t = 25}$ $763620(2^2 3.5.11.13.89)N$

$1050780(2^2 3.5.83.211)$

$1086180(2^2 3.5.43.421)$

$1141980(2^2 3.5.7.2719)$

$1469220(2^2 3.5.47.521)$

$1537500(2^2 3.5^5 41)$

$1088340(2^2 3.5.11.17.97)$

$1451820(2^2 3.5.24197)$

$1451940(2^2 3.5.7.3457)$

$1867740(2^2 3.5.7.4447)$

$2402340(2^2 3.5.40039)$

$2402460(2^2 3^4 5.1483)$

$1248180(2^2 3.5.71.293)$

$1291980(2^2 3.5.61.353)$

$1341780(2^2 3.5.11.19.107)$

$1768620(2^2 3.5.7.4211)$

$2274900(2^2 3.5^2.7583)$

$1668780(2^2 3^2 5.73.127)$

$1172820(2^2 3.5.11.1777)$

$1387500(2^2 3.5^5 37)$

$988260(2^2 3.5.7.13.181)$

$1457820(2^2 3^2 5.7.13.89)$

$1566180(2^2 3^2 5.7.11.113)$

$1717020(2^2 3^2 5.9539)$

$1144980(2^2 3^2 5.6361)$

Remark The new t-cycles in sections 4 and 5 have been found by a systematic computer search for all cycles of the form $(u\,v_0, u\,v_1, \ldots, u\,v_{t-1})$ with $\min_{(i)} (u\,v_i) = \text{bound}_1$, $\max_{(i)} (u\,v_i) < \text{bound}_2$ and $t \leqq 50$. The following cases were considered:

$u = 60,$ $\text{bound}_1 \leqq 6*10^6,$ $\text{bound}_2 = 10*10^6$

$u = 60,$ $6*10^6 <$ $\text{bound}_1 \leqq 10.8*10^6,$ $\text{bound}_2 = 15*10^6$

$u = 60,$ $10.8*10^6 <$ $\text{bound}_1 \leqq 14.4*10^6,$ $\text{bound}_2 = 20*10^6$

$u = 90,$ $\text{bound}_1 \leqq 6*10^6,$ $\text{bound}_2 = 10*10^6$

$u = 90,$ $6*10^6 <$ $\text{bound}_1 \leqq 10.8*10^6,$ $\text{bound}_2 = 15*10^6$

$u = 90,$ $10.8*10^6 <$ $\text{bound}_1 \leqq 16.2*10^6,$ $\text{bound}_2 = 20*10^6$

TABLE 8 Unitary amicable pairs constructed from ordinary amicable pairs

PART 1
(the ordinary amicable pairs are squarefree)

g.c.d.	remaining parts	from no. in [5]	number of isotopic un. am. pairs, found with Theorem 3.2
2.5a	7.19.107,47.359 H	18	5
	11.41.239,17.29.223 H	43	1
	11.13.809,19.6803 H	45	2
	7.21599,19.47.179 H	54	5
	11.17.19.47,239.863 H	55	1
	7.89.359,23.59.179 H	58	5
	7.60659,23.29.673 H	70	5
	7.163.449,19.59.491 H	75	5
	7.107.719,17.179.191 H	79	4
	7.11.11369,757.1439 H	98	2
	11.19.41.103,31.179.181 H	99	2
	7.19.7127,71.79.197 H	105	5
	7.131.2339,19.53.2287 H	146	5
	11.19.89.383,17.359.1279 H	210	1
	17.19.149.163,11.491.1499 H	219	1
	7.29.67.647,47.89.2447 H	227	5
	7.863.2579,23.29.24767 H	258	5
	13.19.179.383,23.59.79.167	262	5
	11.19.115877,17.61.24919 H	283	1
	7.11.929.953,2879.29573 H	335	2
	7.11.929.1019,2447.37199 H	340	2
	17.19.71.90149,11.647.300499 H	537	1
	13.23.139.63737,11.5879.42491 H	551	2
	11.23.71.1399,29.59.83.191	David	2
2.5a11	53.1759,59.1583 H	109	2
2.5a11.59	587.303731,727.245321	760	2
2.5a11.61	239.161039,38649599 H	681	2
2.5a11.83	79.3664781,5351.54779	796	2
2.5a11.89	109.2563199,191.1468499	800	2
2.5a11.109	59.298223,607.29429	669	2
2.5a11.167	41.14328599,1259.477619	870	2
2.5a11.229	43.494639,197.109919 H	715	2
2.5a11.809	29.1708607,1759.29123	827	2

TABLE 8 (cont.)

g.c.d.	remaining parts	from no. in [5]	number of isotopic un. am. pairs, found with Theorem 3.2
2.5a13	23.2339,53.1039 H	87	5
	17.197.2339,1619.5147 H	360	4
	17.179.5381,2339.7451 H	406	4
	19.89.70979,1039.122849 H	523	5
	19.83.129011,5039.43003 H	550	5
2.5a13.59	43.1352987,167.354353	705	3
2.5a17	13.47.2549,359.4759 H	288	4
	11.101.1889,1427.1619 H	305	1
	11.101.3659,719.6221 H	336	1
	13.41.23459,3331.4139 H	405	4
	11.89.227629,1699.144611 H	567	1
2.5a19	11.59.15199,151.71999 H	396	2
	11.47.27739,359.44383 H	419	2
	11.61.538649,139.2862539 H	601	2
	11.41.34154399,9629.1787519 H	804	2
2.5a19.37	29.73.491,179.6067 H	478	5
	29.47.1627,2344319	522	5
2.5a29	7.67.2021183,24683.44543	684	5
2.5a31	7.30689,59.4091 H	204	5
2.5a47.67	7.2550689,107.188939	720	5
2.5a67	7.59.401,31.6029 H	243	5
2.5a79	11.23.7109,17.113759 H	383	1
2.5a107.1069.2137.25643	7.5538887,17.2461727 H	1077	4
2.5a929	7.11.5573,535103 H	446	2
2.7a	11.13.29.47,19.23.503 H	61	7 H
	5.13.17.293,71.6173 H	73	4
	5.13.83.191,31.71.587 H	127	5
	5.31.7853,13.43.2447 H	135	3
	5.539783,13.41.53.101 H	177	5
	5.11.97.26212247,23.6803.1132627 H	782	2
	5.13.23.28687,43.223.5867	David	3
2.7a11	13.71.241,23.10163 H	168	7 H
	13.19.10889,83.36299 H	313	7 H
	13.43.13499,29.359.769 H	368	7 H
	19.53.7699,17.149.3079 H	370	7 H
	13.191.5939,19.307.2591 H	411	7 H

TABLE 8 (cont.)

g.c.d.	remaining parts	from no. in [5]	number of isotopic un. am. pairs, found with Theorem 3.2
2.7a11.43	13.131.1289,139.17027 H	516	7 H
2.7a13	11.103.149,17.10399 H	160	5 H
	11.17.1039,53.4159 H	172	5 H
	11.79.1637,23.59.1091	David	7
2.7a13.181	11.499559,17.229.1447 H	660	5 H
2.7a17	5.101.797,113.4283 H	234	4
	5.47.173501,1223.40823 H	494	4
	5.47.33195287,1181.8088191 H	777	4
2.7a17.101	5.309224831,4283.433087	919	4
2.7a19	11.13.71.113,83.107.151	David	7
2.7a19.61.853	11.3889679,17.37.68239 H	989	7 H
2.11a	5.23.43.67,7.197.271 H	89	2
2.17a	7.11.67.1968353,5.23.1223.72901 H	691	1
3.5.7	13.47.269,23.29.251 H	136	0
	11.13.37.3779,24131519 H	403	0
	13.17.19.463,383.6089	David	0
3.5.7.11a	503.1319,769.863 H	344	3
	293.5279,1231.1259 H	395	3
	347.23099,449.17863 H	492	3
	233.1019479,1091.218459 H	683	3
3.5.7.13.79	269.1511743,467.872159	929	0
3.5.7.19.31	139.1081403,167.901169	865	0
3.5.7.23	17.41.229,107.1609 H	308	0
	13.137.149,139.2069 H	329	0
3.5.11a	7.17.439,23.43.59 H	96	1

TABLE 8 (cont.)

PART 2
(the ordinary amicable pairs are not squarefree)

g.c.d.	remaining parts	from no. in [5]	number of isotopic un. am. pairs, found with Theorem 3.2
2.5E2.7.13a	19.359,47.149	111	7
(2.5E2.31)	29.41.59,179.419	241	7
	17.109.149,107.2749	314	6
	19.59.599,79.8999	361	7
2.5E2.7.13a79	17.7109,127979	517	6
(2.5E2.31.79)			
2.5.7E2a13	47.65519,1663.1889	607	5
(2.7E2.13.19)	47.67157,1511.2131	608	5
2.5.7E2a	13.17.41,97.107	134	4
(2.7E2.19)			
2.5.7E2a23	11.13523,162287	471	2
(2.7E2.19.23)			
2E6.3.5.13	11.17.19.47,31.71.89	36	0
(2E2)			
2E6.3.5.11.13	17.263,43.107	22	0
(2E2.11)	19.197.443,53.73.439	211	0
	17.29.16631,263.34019	307	0
	19.1259.2969,29.149.16631	429	0
	17.107.1038311,37.4751.11177	614	0
2E6.3.5.11.13.23			
(2E2.11.23)	131.36988691,3041.1605031	830	0
2E6.3.5.13.19	11.113.7774829,17.97.773.7789	739	0
(2E2.19)	11.151.34618949,23.37.569.121469	825	0
2E6.3.5.13.19.29.61			
(2E2.19.29.61)	17.2957767,131.403331	845	0
2E6.3.5.13.19.37			
(2E2.19.37)	11.44172449,41.1109.11369	767	0
2E6.3.5.13.23.53			
(2E2.23.53)	11.18943259,17.2437.5179	751	0

TABLE 8 (cont.)

g.c.d.	remaining parts	from no. in [5]	number of isotopic un. am. pairs, found with Theorem 3.2
2E10.3.5.7.41	17.79,23.59	6	0
(2E3)	17.29.47,59.431	21	0
	13.23.149,199.251	26	0
	13.23.251,97.863	31	0
	11.29.239,191.449	32	0
	11.31.233,127.701	34	0
	29.47.59,17.4799	35	0
	17.19.281,53.1879	37	0
	11.59.173,47.2609	40	0
	13.23.1109,71.5179	59	0
	11.163.191,31.11807	62	0
	11.23.1619,647.719	65	0
	11.23.1871,467.1151	67	0
	17.71.439,23.131.179	69	0
	11.23.2543,383.1907	76	0
	11.31.2099,79.10079	81	0
	17.53.1039,23.179.233	90	0
	17.79.769,29.43.839	95	0
	11.211.503,47.83.317	103	0
	11.71.1801,67.107.211	116	0
	17.47.2239,23.167.479	126	0
	11.71.2459,53.163.239	131	0
	17.103.1289,19.107.1117	140	0
	11.79.2879,47.149.383	143	0
	17.23.37.173,1367.2087	144	0
	19.23.29.223,1439.2239	150	0
	13.139.1979,23.349.461	159	0
	19.23.53.191,71.69119	174	0
	11.359.1223,29.271.647	180	0
	13.37.10079,47.139.797	182	0
	17.59.5641,19.433.701	186	0
	13.29.16127,59.293.383	192	0
	13.431.1511,23.107.3527	206	0
	13.23.83.347,587.16703	208	0
	11.71.11689,59.83.2003	212	0
	11.59.14489,53.137.1399	217	0
	13.31.53.457,167.65951	218	0
	13.990719,29.47.9631	239	0
	19.71.9719,23.47.12149	240	0
	13.127.10169,23.223.3389	252	0
	19.53.22679,17.719.1889	267	0
	19.53.26861,17.659.2441	277	0
	13.659.3797,19.593.2953	287	0
	19.53.36721,17.601.3659	296	0
	23.29.127.443,31.89.14207	298	0
	11.1877.2447,31.101.16901	311	0

TABLE 8 (cont.)

g.c.d.	remaining parts	from no. in [5]	number of isotopic un. am. pairs, found with Theorem 3.2
2E10.3.5.7.41	13.89.55579,29.97.23819	319	0
(2E3)	13.863.6029,23.89.33767	323	0
(cont.)	13.23.61.4517,3347.28111	331	0
	17.19.270143,47.1259.1607	337	0
	17.19.291199,47.1091.1999	343	0
	11.67.164429,53.101.24359	355	0
	11.59.383.503,47.863.3359	357	0
	19.59.138401,17.263.34949	375	0
	11.499.29429,29.149.39239	378	0
	17.19.591623,47.809.5477	386	0
	19.53.214541,17.521.24659	391	0
	11.227.114847,31.151.64601	412	0
	17.29.37.18311,71.5218919	418	0
	11.139.223439,31.251.46549	420	0
	11.911.42499,37.67.179999	434	0
	17.43.639007,23.151.138731	442	0
	19.23.29.47189,197.3431999	457	0
	19.23.223.8861,31.29776319	475	0
	11.79.995651,53.83.210719	476	0
	13.1061.102499,19.353.215249	503	0
	11.103.1732799,31.607.111149	525	0
	13.19.131.69191,2239.1141667	532	0
	13.23.59.148367,29567.101159	538	0
	11.23.257.44893,24767.134681	546	0
	13.23.59.210143,25343.167159	556	0
	11.29.79.182239,48239.108799	565	0
	11.113.4113059,29.3527.53161	572	0
	13.27.89.146383,19.293.972407	574	0
	11.29.79.211499,42299.143999	575	0
	13.23.59.325439,23039.284759	577	0
	13.23.59.354551,22751.314159	579	0
	11.29.79.264599,37799.201599	583	0
	11.29.79.292979,36479.231299	589	0
	13.17.449.79159,55411.161999	592	0
	13.17.479.92177,6803.1638719	610	0
	13.19.1993.26099,149.97147679	624	0
	13.23.59.1117079,20879.1078559	651	0
	13.9521.556159,29.47.51486511	717	0
	13.23.59.4594127,20327.4556159	728	0
	13.17.449.3387971,28619.13424039	797	0
	13.17.443.3434129,119447.3216779	798	0
	13.9371.7391159,29.47.673457861	851	0
	13.11807.6742199,19.271.204883559	861	0
	17.19.7699.1261459,47.769.94609499	909	0
	11.59.113.349,79.449.797	David	0
	11.23.349.1439,2999.48383	David	0

TABLE 8 (cont.)

g.c.d.	remaining parts	from no. in [5]	number of isotopic un. am. pairs, found with Theorem 3.2
2E10.3.5.7.17.41	71.1223.1172663,105407.980423	881	0
(2E3.17)	71.1223.5025239,91367.4847039	946	0
	71.1223.8663003,89963.8486207	957	0
2E10.3.5.7.19.41	67.1367,101.911	125	0
(2E3.19)	47.179.1883051,24623.660719	789	0
	89.113.191,1367.1439	David	0
2E10.3.5.7.19.41.137			
(2E3.19.137)	83.218651,18366767	696	0
2E10.3.5.7.23.41	29.137.2887,359.33211	404	0
(2E3.23)	29.137.599,827.2999	David	0
2E10.3.5.7.29.41	19.2087,173.239	101	0
(2E3.29)	17.1217.20939,251.1821779	621	0
	19.107.233159,647.777199	630	0
2E10.3.5.7.31.41	23.61.449,199.3347	259	0
(2E3.31)	17.107.4339,8436959	397	0
2E10.3.5.7.37.41	23.47.73,85247	151	0
(2E3.37)			
2E10.3.5.7.41.83	11.331.383,71.21247	352	0
(2E3.83)			
2E10.3.5.7.41.467			
(2E3.467)	11.532379,37.89.1867	542	0

TABLE 8 (cont.)

g.c.d.	remaining parts	from no. in [5]	number of isotopic un. am. pairs, found with Theorem 3.2
2E2.3.5E2a (3E2.5)	$\underline{7}$.11.29,31.89 H	14	1 H
	$\underline{7}$.19.23.71,31.79.107	108	1
	$\underline{7}$.19.2663,11.73.479	132	1
	$\underline{7}$.11.59.89,31.107.149	141	1
	$\underline{7}$.17.29.479,19.71.1439	214	1
	$\underline{7}$.11.17.4259,53.283.479	David	1
2E2.3.5E2a$\underline{7}$ (3E2.5.7)	53.1889,102059	162	1
	71.4339,239.1301	236	1
	71.5879,223.1889	249	1
	59.708959,421.100799	513	1
	83.149.5807,2879.25409	545	1
	59.461.9337,8819.29347	613	1
	97.113.25849,12539.23029	618	1
	83.149.42767,1889.285119	657	1
	83.139.78539,19403.47599	685	1
	83.139.93683,16879.65267	690	1
	83.139.108863,15679.81647	699	1
	59.419.147377,54449.68207	758	1
	59.419.170741,40949.105071	765	1
	59.419.182159,38639.118799	769	1
	53.2099.49633,26891.209299	775	1
	59.419.233279,33599.174959	776	1
	59.419.244199,32999.186479	778	1
	59.419.325939,30319.270899	794	1
	53.4073.42239,3779.2458367	802	1
	59.419.636473,27449.584303	832	1
	53.1931.198769,81971.252979	841	1
	53.1931.211319,77279.285281	846	1
	59.419.1274249,26249.1223279	867	1
	83.139.5742623,11807.5719279	900	1
	53.1889.886463,139967.646379	910	1
	59.419.5316959,25439.5266799	925	1
	53.1889.1411829,121013.1190699	930	1
2E2.3.5E2a$\underline{7}$.107 (3E2.5.7.107)	3209.4493,14425739	712	1
2E2.3.5E2a$\underline{7}$.137 (3E2.5.7.137)	307.24659,839.9041	688	1
2E2.3.5E2a$\underline{7}$.181 (3E2.5.7.181)	149.121631,719.25339	753	1
2E2.3.5E2a$\underline{7}$.251 (3E2.5.7.251)	89.28571831,31123.82619	974	1
	101.78010799,739.10752839	992	1

TABLE 8 (cont.)

g.c.d.	remaining parts	from no. in [5]	number of isotopic un. am. pairs, found with Theorem 3.2
2E2.3.5E2a7.379	79.6653723,757.702239	947	1
(3E2.5.7.379)			
2E2.3.5E2a11.19	139.7523,569.1847	496	2
(3E2.5.11.19)	193.75239,227.64019	642	2
2E2.3.5E2a11.29	43.6263,47.5741	445	2
(3E2.5.11.29)			
2E2.3.5E2.13a	11.19,239 H	15	3 HH
(3E2.5.13)	19.47,29.31	30	3 H
	11.199,29.79	48	3 H
	19.23.43,47.439	114	3
	11.31.89,127.269	137	3
	11.47.59,71.479	138	3
	11.23.239,179.383	173	3
	23.29.97,19.3527	178	3
	17.43.149,19.5939	203	3
	11.19.1409,449.751	264	3
	11.258299,29.59.1721	389	3
	11.23.79.1051,24238079	507	3
	11.59.644999,29.719.21499	677	3
	11.19.211.14699,747935999	697	3
2E2.3.5E2.13a19	29.569,17099	268	3
(3E2.5.13.19)	37.1583,227.263	330	3
	29.44687,1063.1259	515	3
	31.184337,263.22343	594	3
	37.113.28499,7219.17099	764	3
	37.113.255587,4483.246923	874	3
	29.569.113021,28349.68171	898	3
	29.569.117779,27179.74099	903	3
	29.569.125113,25849.82763	906	3
	29.569.152459,23099.112859	911	3
	29.569.289381,19531.253349	939	3
	37.113.1165187,4363.1156643	940	3
2E2.3.5E2.13a29	17.1217.7039,79.1929311	792	3
(3E2.5.13.29)			
2E2.3.5E2.13a41	23.29.3361,71.33619	585	2
(3E2.5.13.41)	11.2686319,223.143909	736	2
2E2.3.5E2.13a79	11.72047,37.22751	564	3
(3E2.5.13.79)			
2E2.3.5E2.13a79.157	17.5023,23.3767	726	3
(3E2.5.13.79.157)			

TABLE 8 (cont.)

g.c.d.	remaining parts	from no. in [5]	number of isotopic un. am. pairs, found with Theorem 3.2
2E2.3.5E2a17.19 (3E2.5.17.19)	23.19379,37.12239	472	2
2E2.3.5E2a19 (3E2.5.19)	7.227,37.47	50	1
2E2.3.5E2a19.37 (3E2.5.19.37)	7.887,7103	270	1
2E2.3.5E2a31 (3E2.5.31)	7.929,11.619	100	1
2.3E3a7 (3E2.7.13)	5.17,107 H 5.17.1187,131.971	12 222	1 1
2.3E3a7.37 (3E2.7.13.37)	5.14207,191.443	407	1
2.3E3.7.41 (3E2.7.13.41)	5.4591,163.167	346	0
2.3E3.7.41.163 (3E2.7.13.41.163)	5.977,5867	552	0
2.3E3a7.131 (3E2.7.13.131)	5.4493.6287,23.7064567	886	1
2.3E3a11.17.373 (3E2.11.13.17.373)	5.47.2237,71.8951	824	1
2E2.3.7a (3E2.7E2.13.19)	11.10499,89.1399 11.79.2029,1948799 11.83.5711,2351.2447 11.83.38821,1061.36847 11.359.9463,107.378559 11.83.63439,1039.61487 11.83.83591,1031.81647 17.23.1335949,3079.187379	508 665 722 817 821 839 862 941	6 6 6 6 6 6 6 6
2E2.3.7a23 (3E2.7E2.13.19.23)	83.1931,162287	700	6
2E2.3.7a29 (3E2.7E2.13.19.29)	41.173,7307	544	5
2E2.3.7a83 (3E2.7E2.13.19.83)	17.149.829,107.20749	894	6
2E2.3.7a307 (3E2.7E2.13.19.307)	17.41.613,107.4297	884	5

TABLE 8 (cont.)

g.c.d.	remaining parts	from no. in [5]	number of isotopic un. am. pairs, found with Theorem 3.2
2.3E3.7a	11.17.227,23.37.53	82(170)	6
(3E3.5)	11.13.17.107,53.6047	171	3
	17.29.31.41,13.71.719	225	1
2.3E3.7a11	23.659,79.197	149(254)	6
(3E3.5.11)	23.7523,53.3343	286(388)	6
	17.241.1999,2903.2999	505(606)	6
	17.409.2111,439.35423	541(641)	6
	17.293.3299,659.26459	547(646)	6
	17.211.6863,2861.9151	563(670)	6
	23.509.2441,59.498167	573(680)	6
	17.197.21059,7019.10691	625(727)	6
	19.4113647,131.419.1483	635(735)	6
	17.197.49139,4211.41579	676(770)	6
	17.197.135089,3761.127979	732(822)	6
	19.89.910909,38219.42899	786(882)	6
	19.89.1205819,26729.81199	805(893)	6
	19.89.1590467,24097.118799	820(908)	6
	17.197.1379069,3581.1372139	847(926)	6
2.3E3.7a11.43	67.874619,1289.46103	814(905)	6
(3E3.5.11.43)			
2.3E3.7a11.131	23.26723,271.2357	637(737)	6
(3E3.5.11.131)			
2.3E3.7a13	11.467.33569,10529.17903	687	3
(3E3.5.13)	11.467.60779,7019.48623	716	3
	11.467.488239,5743.477359	826	3
2.3E3.7a13.23	827.20071,1103.15053	731	3
(3E3.5.13.23)			
2.3E3.7a13.1013	11.4051,48623	611	3
(3E3.5.13.1013)			
2.3E3.7a17.19	79.3229,199.1291	502(599)	6
(3E3.5.17.19)	101.113.84811,17707.55691	927(978)	6
	101.113.245251,12907.220931	960(994)	6
	101.113.298343,12647.274283	966(998)	6
	101.113.407483,12347.383723	975(1001)	6
	101.113.593291,12107.569771	983(1007)	6
	101.113.732731,12011.709307	985(1009)	6
2.3E3.7a17.31.61	67.4391,101.2927	763(857)	6
(3E3.5.17.31.61)			

TABLE 8 (cont.)

g.c.d.	remaining parts	from no. in [5]	number of isotopic un. am. pairs, found with Theorem 3.2
2.3E3.7a19.37.73 (3E3.5.19.37.73)	23.6569,107.1459	754(840)	6
2.3E3.7a23 (3E3.5.23)	11.19.367,79.1103	281(384)	6
2.3E3.7a23.229.457 (3E3.5.23.229.457)	13.17.2741,107.6397	973	3
2.3E3.7a113 (3E3.5.113)	13.17.6553,11.137633	543	3
2.3E3.5E2.7a (3E3.5E3)	29.41.43.59,19.131.1259	498(539)	1
2.3E3.5E2.7a13 (3E3.5E3.13)	149.449,67499	423(467)	1
	191.589049,271.415799	831(869)	1
	149.461.291857,14699.1375901	997(1008)	1
	149.449.395039,148139.179999	1000(1012)	1
	149.449.438899,115499.256499	1002(1015)	1
	149.449.521399,98999.355499	1005(1017)	1
	149.449.603899,91499.445499	1006(1019)	1
	149.449.1076399,77999.931499	1016(1025)	1
	149.449.1558619,74219.1417499	1022(1030)	1
	149.449.1707947,73547.1567499	1024(1031)	1
	149.449.2366099,71699.2227499	1026(1033)	1
	149.449.6203411,69011.6067499	1034(1040)	1
	139.569.6594659,287279.1831849	1035(1042)	1

TABLE 9 Numbers a and b, satisfying $\sigma^*(a)/a = \sigma^*(b)/b$, used in TABLE 8 for the construction of unitary amicable pairs

a	dist. factors	b
2.5		2E3.3.5 2E4.3.5.17 2E5.3.5.11 2E7.3.5.11.43 2E8.3.5.11.43.257
2.7	5	2E3.3.7 2E4.3.7.17 2E5.3.7.11 2E7.3.7.11.43 2E8.3.7.11.43.257
2.7	11,13	2.3E2.5E3.7E2 2E2.3.5E3.7E2 2E2.5.7 2E3.3.7 2E3.3E2.5.7 2E4.3.7.17 2E4.3E2.5.7.17
2.7	11,17	2.3E2.5E3.7E2 2.5E2.7E2.13 2E2.3.5E3.7E2 2E2.5.7 2E3.3.5E2.7E2.13 2E3.3.7 2E3.3E2.5.7
2.11	5,7	2E3.3.11 2E4.3.11.17
2.17	5,7,11	2E3.3.17
2.3E3	5	2.3E4.41
2.3E3.7		2.3E3.5E2.7E2.13 2.3E4.5E2.7E2.13.41 2.3E4.7.41 2E2.3E2.5E2.7.13 2E2.3E3.5.7 2E2.3E4.5.7.41

a	b
2.5E2.7.13	2.3E2.5E3.7 2E2.3.5E3.7 2E3.3.5E2.7.13 2E4.3.5E2.7.13.17 2E5.3.5E2.7.11.13 2E7.3.5E2.7.11.13.43 2E8.3.5E2.7.11.13.43.257
2.5.7E2	2E3.3.5.7E2 2E4.3.5.7E2.17 2E5.3.5.7E2.11 2E7.3.5.7E2.11.43 2E8.3.5.7E2.11.43.257
2E2.3.5E2	2.3E2.5E2 2E6.3.5E2.7.13
2E2.3.5E2.13	2.3E2.5E2.13 2.3E3.5 2.3E4.5.41
2E2.3.7	2.3E2.5E2.7E2.13 2.3E2.7 2.3E3.5.7E2 2.3E4.5.7E2.41 2E2.3.5E2.7E2.13 2E2.3E2.5.7
2.3E3.5E2.7	2.3E4.5E2.7.41
3.5.7.11	2E5.3.5.7.11E2.31.61 2E7.3.5.7.11E2.31.43.61 2E8.3.5.7.11E2.31.43.61.257
3.5.11	2E5.3.5.11E2.31.61 2E7.3.5.11E2.31.43.61 2E8.3.5.11E2.31.43.61.257

TABLE 10 Periodic unitary aliquot sequences; starting values
(ϵ(40000, 100000]), preperiods and enpoints.

40002	76	56430	40524	8	54	41046	10	2178	41678	10	30	42104	3	42	42578	5	126
40004	7	42	40530	34	2178	41052	8	42	41680	4	60	42114	82	56430	42596	6	126
40006	7	30	40540	7	114	41058	9	2178	41682	28	2178	42122	6	30	42600	6	114
40010	9	90	40544	3	126	41072	6	30	41688	5	1140	42126	81	56430	42606	38	56430
40014	32	56430	40546	7	30	41082	76	56430	41694	27	2178	42142	7	90	42610	5	54
40018	10	114	40554	27	56430	41100	10	30	41700	7	90	42146	10	90	42614	6	30
40022	10	30	40556	6	30	41110	6	90	41706	26	2178	42152	6	30	42624	7	42
40032	4	114	40564	24	56430	41116	6	126	41710	7	30	42170	10	30	42632	4	90
40036	12	1890	40568	6	30	41120	6	30	41716	24	56430	42172	7	114	42636	9	54
40038	186	56430	40584	8	30	41128	5	42	41720	8	30	42186	29	56430	42648	10	30
40048	8	30	40588	8	30	41136	8	42	41728	7	30	42188	2	2958	42658	11	54
40050	185	56430	40594	7	114	41140	4	126	41736	8	30	42198	15	2178	42662	7	42
40052	6	30	40604	7	30	41152	6	42	41738	5	126	42216	10	30	42664	7	42
40060	7	30	40628	6	90	41168	6	30	41744	5	90	42226	7	30	42676	5	54
40094	8	30	40650	29	56430	41194	6	90	41784	6	90	42236	4	60	42688	5	30
40098	17	2178	40654	9	90	41218	6	42	41796	7	30	42254	10	42	42692	6	30
40114	7	90	40658	5	126	41230	11	90	41800	7	30	42258	33	2178	42704	4	126
40128	9	42	40660	6	90	41232	4	60	41802	57	1291050	42266	8	54	42716	7	30
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40140	12	30	40682	4	60	41252	6	60	41814	56	1291050	42270	32	2178	42726	34	2178
40150	5	126	40686	79	56430	41258	10	30	41826	5	56430	42272	5	90	42728	4	1890
40168	8	90	40698	78	56430	41260	7	54	41838	4	56430	42274	7	60	42736	8	30
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40242	5	56430	40794	36	2178	41346	16	56430	41922	203	56430	42346	11	30	42810	20	2178
40256	5	42	40806	30	56430	41356	6	30	41932	7	30	42348	9	1890	42814	5	54
40272	7	30	40818	74	56430	41360	5	42	41940	4	24180	42352	5	54	42820	7	30
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40304	5	54	40834	5	90	41382	39	2178	41958	13	2178	42392	5	114	42846	188	56430
40306	12	42	40840	7	114	41416	3	90	41960	5	90	42396	7	126	42850	5	90
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40338	39	56430	40872	5	90	41428	23	2178	41982	38	56430	42406	11	30	42882	61	56430
40346	5	42	40878	202	56430	41434	7	42	41986	7	30	42416	6	30	42888	13	30
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40460	8	30	40978	9	30	41598	42	56430	42046	6	90	42512	6	42	42946	6	42
40462	9	42	40980	11	30	41616	4	60	42050	6	30	42522	36	2178	42952	7	30
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43018	6	42	43432	9	30	43934	4	114	44442	10	2178	44944	4	2418	45590	8	30
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43028	5	42	43448	6	30	43986	24	2178	44460		44460	44954	7	42	45616	6	42
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43098	39	56430	43508	4	54	44086	6	90	44572	7	114	45090	13	56430	45670	9	30
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43156	21	2178	43590	75	56430	44144	3	90	44628	9	42	45144	8	30	45732	8	42
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43170	84	56430	43638	50	1291050	44182	7	90	44656	7	30	45176	6	30	45786	18	2178
43174	6	114	43642	3	114	44190	196	56430	44690	8	30	45184	5	90	45790	8	126
43182	28	56430	43650	14	2178	44192	8	30	44694	39	56430	45198	79	56430	45794	5	90
43188	7	30	43656	7	60	44200	4	114	44706	5	56430	45202	7	90	45796	23	56430
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43194	36	2178	43662	29	2178	44224	4	54	44720	5	42	45214	11	30	45802	6	54
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43212	6	42	43686	30	56430	44232	7	60	44736	12	30	45258	65	56430	45840	11	30
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43224	6	42	43720	5	126	44244	7	90	44744	4	30	45284	6	90	45858	32	49878
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43232	5	54	43726	7	90	44278	11	30	44752	4	2178	45306	28	2178	45870	31	49878
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43236	4	30	43750	11	54	44292	7	114	44772		44772	45334	9	90	45892	6	42
43242	27	56430	43752	11	30	44304	10	30	44776	7	90	45336	7	60	45894	82	56430
43250	5	126	43758	35	2178	44308	5	90	44778	65	56430	45342	22	2178	45898	9	30
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43260	22	2178	43766	10	42	44316	4	54	44790	28	38682	45372	6	42	45918	11	2178
43274	11	30	43772	3	2178	44326	5	90	44792	6	42	45384	14	30	45942	23	2178
43278	21	2178	43778	8	30	44340		44340	44802	45	56430	45402		45402	45954	10	2178
43284	10	30	43784	6	30	44346	27	56430	44808	9	30	45414	8	56430	45956	10	54
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43314	16	1890	43852	6	30	44362	9	54	44826	12	2178	45440	6	42	45966	29	2178
43316	8	126	43860	7	90	44370	195	56430	44838	46	56430	45456	7	30	45972	8	42
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43332	6	90	43878	13	2178	44376	7	30	44856	6	126	45472	6	42	45978	12	2178
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43344	5	30	43908	6	60	44388	7	42	44868	4	2178	45484	5	126	45984	9	30
43350	55	56430	43916	8	30	44392	3	114	44872	3	90	45508	5	42	45994	9	90
43368	11	30	43918	11	30	44394	42	2178	44906	6	30	45514	9	42	46004	7	30
43374	29	2178	43920	12	30	44414	6	30	44910	14	56430	45516	7	54	46012	9	54
43386	28	2178	43924	6	90	44416	5	90	44922	12	2178	45522	41	56430	46014	16	2178
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43416	4	90	43930	9	90	44422	11	30	44934	11	2178	45562	9	30	46020	18	30
43428	11	30	43932	5	114	44436	4	90	44936	4	90	45572	6	126	46026	15	2178

46038	137	2178	46638	6	56430	47146	12	90	47716	6	126	48212	6	42	48636	4	90
46040	6	30	46650	134	56430	47160	8	30	47718	204	56430	48220	6	90	48644	8	30
46044	27	2178	46656	3	42	47166	65	56430	47736	4	1140	48228	9	30	48658	3	3522
46050	136	2178	46666	9	54	47190	103	56430	47760	7	42	48234	132	2178	48660	6	24180
46052	4	1878	46682	7	114	47200	3	114	47764	30	56430	48236	5	2418	48668	7	42
46062	79	56430	46696	5	54	47202	31	56430	47766	135	2178	48238	7	30	48684	6	54
46074	63	1291050	46704	4	90	47208	10	30	47774	10	30	48246	131	2178	48686	10	30
46076	4	60	46708	34	2178	47214	30	56430	47782	7	42	48252	9	30	48700	5	90
46078	11	30	46716	7	54	47218	5	90	47788	2	4158	48266	4	90	48708	3	2142
46082	7	54	46726	7	90	47220	15	90	47802	132	2178	48272	6	30	48720	7	54
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46112	6	90	46750	7	90	47226	18	2178	47814	17	2178	48282	28	2178	48728	5	42
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46132	7	114	46760	4	114	47238	35	2178	47844	9	42	48286	9	30	48738	3	56430
46144	3	42	46776	9	42	47246	6	30	47848	7	126	48288	7	126	48740	6	54
46148	5	42	46790	10	90	47250	34	2178	47852	6	42	48290	8	90	48750	2	56430
46152	8	42	46806	41	2178	47252	12	54	47868	7	42	48322	7	30	48752	6	30
46182	15	2178	46812	8	42	47262	14	2178	47874	136	2178	48332	6	30	48756	12	126
46184	5	114	46854	39	56430	47268	5	90	47876	8	126	48334	7	30	48762	23	56430
46192	4	60	46856	6	126	47270	7	54	47880	7	1140	48336	5	30	48768	8	42
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46218	49	56430	46860	12	90	47274	13	2178	47918	11	42	48348	5	42	48780	5	24180
46230	48	56430	46866	82	56430	47286	12	2178	47928	11	30	48354	16	1890	48786	30	2178
46240	6	42	46876	6	126	47320	7	54	47934	31	56430	48360	11	30	48790	10	90
46242	76	56430	46890	36	2178	47336	4	60	47946	65	56430	48362	5	114	48814	9	30
46248	7	60	46900	4	24180	47340	14	90	47948	4	54	48366	15	1890	48816	8	30
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46284	5	42	46924	6	90	47352	7	30	47970	37	2178	48398	10	42	48832	7	30
46288	5	30	46926	33	56430	47354	7	54	47980	5	90	48404	6	54	48834	204	56430
46306	5	90	46932	8	30	47360	5	2178	47982	32	2178	48408	10	30	48846	25	2178
46322	8	90	46938	18	2178	47372	6	30	47984	4	54	48410	10	30	48854	8	90
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46360	7	90	46950	17	2178	47394	56	1291050	48030	40	2178	48450	35	2178	48866	10	90
46368	8	30	46954	10	42	47398	11	42	48036	6	60	48462	35	2178	48872	4	90
46386	27	56430	46962	34	2178	47416	5	30	48042	15	2178	48464	4	90	48882	53	1291050
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46414	9	90	46972	7	42	47430	23	56430	48058	5	90	48468	7	30	48888	4	114
46416	8	1890	46974	6	56430	47438	8	126	48072	8	30	48472	3	126	48894	52	1291050
46426	9	30	46986	5	56430	47452	5	114	48084	7	126	48486	29	2178	48918	29	2178
46434	78	56430	46994	7	114	47470	6	126	48086	7	90	48496	4	30	48934	9	90
46448	6	30	47000	8	30	47482	4	42	48088	7	30	48498	28	2178	48936	9	90
46466	8	90	47002	13	30	47488	4	114	48092	6	30	48508	5	42	48942	30	56430
46470	201	56430	47018	5	42	47492	6	30	48102	11	2178	48518	11	90	48952	3	126
46476	10	30	47034	16	2178	47510	6	126	48104	5	90	48528	7	42	48954	16	2178
46482	3	56430	47040	9	90	47520	7	30	48114	10	2178	48540	7	24180	48960	8	30
46492	6	42	47052	10	42	47586	5	35238	48116	8	30	48544	4	126	48966	27	2178
46512	5	42	47060	8	30	47588	12	30	48140	7	114	48552	9	30	48978	26	2178
46528	3	42	47070	35	2178	47596	6	126	48142	5	90	48562	7	54	48984	10	30
46536	13	30	47078	6	30	47628	5	42	48150	198	56430	48572	8	1890	48990	75	56430
46540	5	126	47080	6	54	47630	10	90	48154	6	54	48584	6	54	48994	9	90
46544	8	54	47084	3	3966	47648	4	54	48162	3	56430	48588	7	42	48996	7	90
46568	8	30	47094	26	2178	47658	65	56430	48168	5	1140	48594	84	56430	49002	23	2178
46574	8	54	47098	5	30	47678	5	42	48170	8	30	48604	6	42	49014	22	2178
46578	20	2178	47100	7	30	47680	7	30	48174	202	56430	48606	77	56430	49026	82	56430
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46590	48	1291050	47118	55	56430	47694	206	56430	48186	2	35238	48624	8	30	49038	81	56430
46604	3	3966	47130	54	56430	47698	12	90	48196	33	56430	48630	42	2178	49044	5	42
46608	8	42	47140	7	30	47706	205	56430	48200	4	90	48632	8	90	49074	27	2178

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98032 : 7 = 30	98544 : 6 = 42	99124 : 9 = 2178	99638 : 12 = 90	
98040 : 13 = 30	98550 : 25 = 2178	99128 : 3 = 126	99646 : 9 = 90	
98044 : 5 = 2178	98554 : 5 = 30	99142 : 6 = 90	99660 : 23 = 30	
98088 : 7 = 54	98576 : 7 = 42	99146 : 11 = 42	99664 : 6 = 2418	
98092 : 6 = 42	98578 : 15 = 126	99150 : 76 = 56430	99686 : 9 = 114	
98094 : 1 = 98106	98580 : 24 = 30	99162 : 89 = 1291050	99690 : 186 = 56430	
98102 : 7 = 42	98600 : 5 = 90	99168 : 14 = 30	99694 : 8 = 42	
98106 = 98106	98608 : 9 = 90	99176 : 8 = 90	99696 : 7 = 30	
98116 : 7 = 54	98620 : 8 = 42	99188 : 5 = 90	99714 : 30 = 2178	
98118 : 8 = 56430	98622 : 42 = 56430	99190 : 13 = 90	99716 : 5 = 1890	

APPENDIX. On the number of different prime factors of unitary t-cycles.

Here we present three theorems about the number of different prime factors of unitary t-cycles. The theorems essentially come from, and are included with the kind permission of, Walter Borho.

If n is a natural number, then $\omega(n)$ means the number of different prime factors of n.

Theorem 1 Let (n, m) be a unitary 2-cycle, n < m. Then

a) $\omega(m) \geqq 2$. b) $\omega(n) \geqq 3$. c) If $\omega(m) = 2$, then $\omega(n) \geqq 6$.

Proof a) is clear. A prime power cannot belong to a unitary cycle, because $s^*(\text{prime power}) = 1$.

b) We have $s^*(n)/n = m/n > 1$, i.e. n is unitary abundant. But a unitary abundant number has at least three different prime factors because $s^*(n) / n \leqq s^*(2.3) / (2.3) = 1$, in case of $\omega(n) = 2$.

c) For abbreviation we write $s^*(k) / k = \alpha(k)$, for any natural number k. Assume, contrariwise, $\omega(m) = 2$ and $\omega(n) \leqq 5$. Then

$$\alpha(n) \leqq \alpha(2.3.5.7.11) = 1152/385 - 1 = 767/385.$$

Because $\alpha(n)\, \alpha(m) = 1$, it follows that

$$(*) \qquad \alpha(m) = \alpha(n)^{-1} \geqq 385/767 = \tfrac{1}{2}(1+3/767) > \tfrac{1}{2}.$$

Let m = PQ, P < Q, be the decomposition of m into two prime powers. If $P \geqq 4$, then $\alpha(m) \leqq \alpha(4.5) = \frac{5}{4} \cdot \frac{6}{5} - 1 = \frac{1}{2}$, contradictory to (*).
Hence P = 2 or P = 3.
If P = 3 and $Q \geqq 11$, then $\alpha(m) \leqq \alpha(3.11) = 5/11 < \frac{1}{2}$. Hence Q < 11 and $m = PQ \leqq 3.7 = 21$. This is impossible ([3]).
If P = 2 then from (*) it follows that $Q \leqq 767 < 1000$. Thus m = PQ < 2000. But again, according to [3], no 2-cycles exist with $\omega(m) = 2$ and m < 2000.
Q.e.d.

<u>Theorem 2</u> There is only one unitary 2-cycle (n, m) with $\omega(n) + \omega(m) < 7$, viz. $(n, m) = (114, 126) = (2.3.19, 2.3^2 7)$.

<u>Proof</u> According to Theorem 1, we only need to investigate the case $\omega(n) = \omega(m) = 3$. Assume $n < m$, then n is unitary abundant.

<u>Lemma</u> If n is unitary abundant and $\omega(n) = 3$, then $n = 70 = 2.5.7$ or $n = 2.3.R$, $(6, R) = 1$.

Indeed, let $n = PQR$, $P < Q < R$, be the decomposition of n into three prime factors. If $P \geqq 3$, then $\alpha(n) \leqq \alpha(3.4.5) = 1$. Hence $P = 2$. If $Q \neq 3$, then $Q \geqq 5$ and $\alpha(n) \leqq \alpha(2.5.9) = 1$, unless $n = 2.5.7 = 70$. This proofs the lemma.

Because $n = 70$ is not a member of a 2-cycle, we can assume $n = 2.3.R$, with R a power of a prime $\geqq 5$. We have $\sigma^*(n) = 3.4(R+1)$, hence $6 \mid m = \sigma^*(n) - n$. Because $4 \mid \sigma^*(n)$, but $4 \nmid n$, we have $2 \parallel m$. Hence m has the form $m = 2.3^\mu S$, where S is a prime power such that $(6, S) = 1$, and $\mu > 1$.

(n, m) form a 2-cycle, hence

$$m+n = 6(R+3^{\mu-1}S) = \sigma^*(n) = 12(R+1) = \sigma^*(m) = 3(3^\mu+1)(S+1).$$

Elimination of R gives for S the equation

$$S = (3^\mu + 5) / (3^{\mu-1} - 1),$$

a monotonically decreasing function of μ. For $\mu = 2$, $S = 7$, hence $R = 19$, as indicated in the Theorem. For $\mu \geqq 3$, we have $4 \geqq S > 3$, which is impossible. Q.e.d.

Without proof, we finally quote

<u>Theorem 3</u> Let X be an arbitrary positive number. The number of unitary t-cycles $(n, m, \ldots)$ (t arbitrary, but fixed) with $\omega(n) \leqq X$, $\omega(m) \leqq X$, ... is <u>finite</u>.

<u>Remark</u>. Theorem 2 can be extended to:
There is only one unitary 2-cycle (n,m) with $\omega(n) + \omega(m) < 8$. The proof is somewhat longer than the proof of Theorem 2, but the same ideas are used.

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