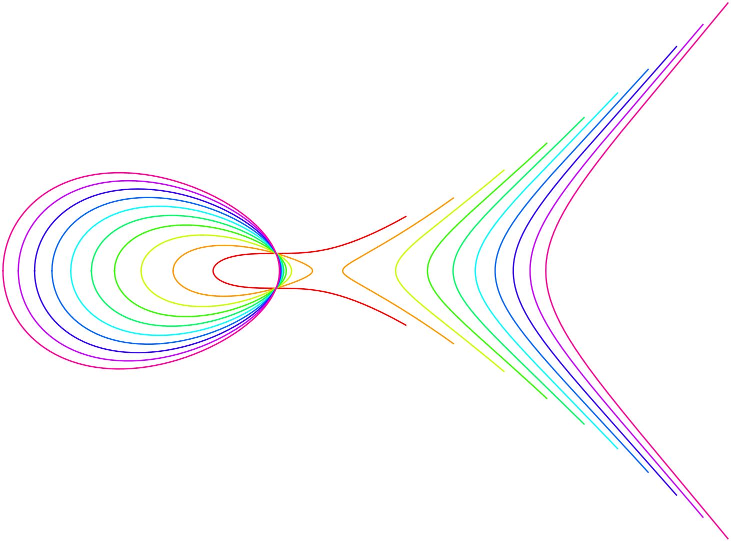
A Whirlwind Tour of Cryptography



Katherine E. Stange, Math 4440/5440 First Day (August 26, 2024)

Ancient Cryptography

א ב ג ד ה ו ז ח ט י כ ל מ נ ס ע פ צ ק ר ש ת

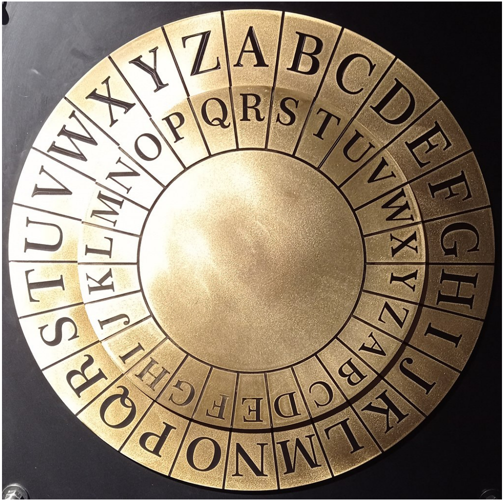
ת ש ר ק צ פ ע ס נ מ ל כ י ט ח ז ו ה ד ג ב א

Atbash Cipher

Jeremiah 25:26 “The king of Sheshach shall drink after them”

(בבל *bbl* → ששך *ššk*)

Ancient Cryptography


A B C D E F G H I J K L M N O P Q R S T U V W X Y Z
R S T U V W X Y Z A B C D E F G H I J K L M N O P Q

Ceasar Wheel

image: Subjectiveart, CC BY-SA 4.0 https://creativecommons.org/licenses/by-sa/4.0, via Wikimedia Commons

Last 500 years

Vigenère Cipher

KEY	1	3	2	4	1	3	2	4	1	3	2	4
PLAINTEXT	A	T	T	A	C	K	A	T	D	A	W	N
CIPHERTEXT	B	W	V	E	D	N	C	X	E	D	Y	R

"impossible of translation" - Scientific American, 1917

Example of a **substitution cipher** (replacing characters)

First World War

	A	D	F	G	V	X
A	c	o	8	x	f	4
D	m	k	3	a	z	9
F	n	w	1	0	j	d
G	5	s	i	y	h	u
V	p	l	v	b	6	r
X	e	q	7	t	2	g

3	4	2	1
D	G	X	G
X	G	D	G
A	A	D	D
D	G	X	G
F	X	D	G
F	D	F	A

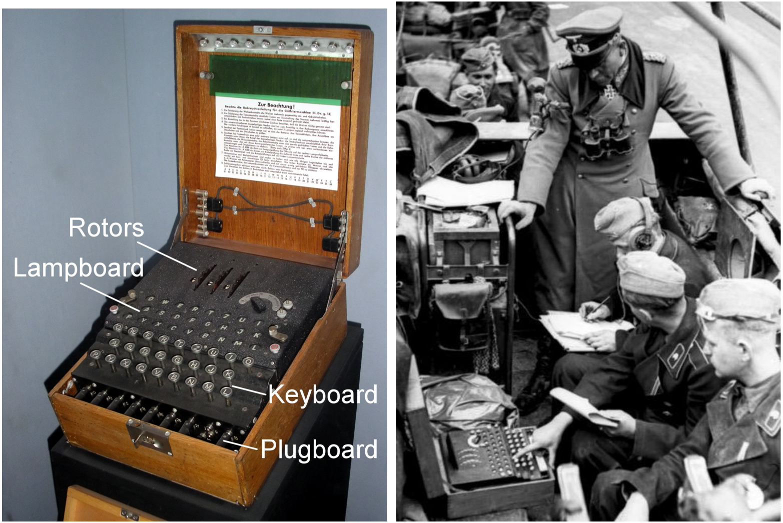
Plaintext: attack at dawn

Step 1: DG XG XG DG AA DD DG XG FX DG FD FA

Ciphertext: GGDGGAXDDXDFDXADFFGGAGXD

Includes an example of a **transposition cipher** (reordering characters)

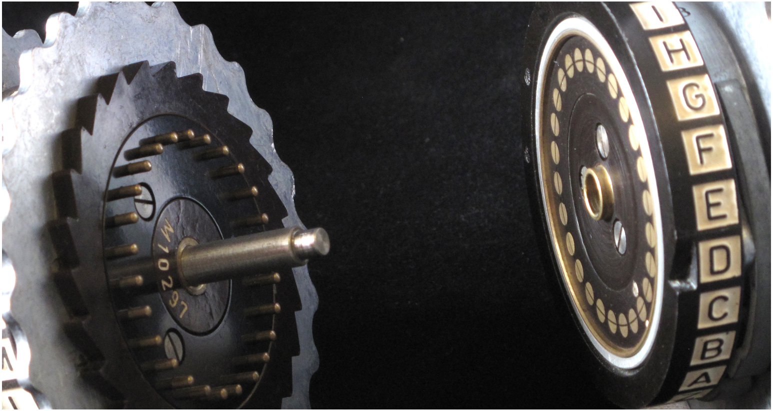
Second World War



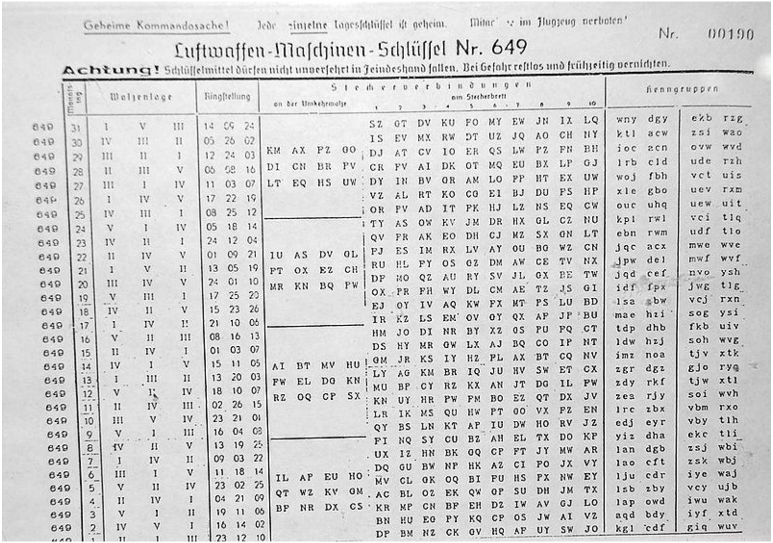
Wartime Enigma Machine

at left: public domain; at right: Bundesarchiv, Bild 101I-769-0229-10A / Borchert, Erich (Eric) / CC-BY-SA 3.0, CC BY-SA 3.0 DE https://creativecommons.org/licenses/by-sa/3.0/de/deed.en, via Wikimedia Commons

Second World War



Second World War



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649	30	IV	III	II	05	26	02		IS	EV	MX	RW	DT	UZ	JQ	AO	CH	NY	ktl	acw	zsi	wao
649	29	III	II	I	12	24	03	KM AX PZ GO	DJ	AT	CV	IO	ER	QS	LW	PZ	FN	BH	ioc	acn	ovw	wvd
649	28	II	III	V	06	08	16	DI CN BR PV	CR	FV	AI	DK	OT	MQ	EU	BX	LP	GJ	lrb	cld	ude	rzh
649	27	III	I	IV	11	03	07	LT EQ HS UW	DY	IN	BV	GR	AM	LO	FP	HT	EX	UW	woj	fbh	vct	uis
649	26	I	IV	V	17	22	19		VZ	AL	RT	KO	CG	EI	BJ	DU	FS	HP	xle	gbo	uev	rxm
649	25	IV	III	I	08	25	12		OR	FV	AD	IT	PK	HJ	LZ	NS	EQ	CW	ouc	uhq	uew	uit
649	24	V	I	IV	05	18	14		TY	AS	OW	KV	JM	DR	HX	GL	CZ	NU	kpl	rwl	vci	tlq
649	23	IV	II	I	24	12	04		QV	FR	AK	EO	DH	CJ	MZ	SX	GN	LT	ebn	rwm	udf	tlo
649	22	II	IV	V	01	09	21	IU AS DV GL	PJ	ES	IM	RX	LV	AY	OU	BG	WZ	CN	jqc	acx	mwe	wve
649	21	I	V	II	13	05	19	PT OX EZ CH	RU	HL	FY	OS	GZ	DM	AW	CE	TV	NX	jpw	del	mwf	wvf
649	20	III	IV	V	24	01	10	MR KN BQ PW	DF	HO	QZ	AU	RY	SV	JL	GX	BE	TW	jqd	cef	nvo	ysh
649	19	V	III	I	17	25	20		OX	PR	FH	WY	DL	CM	AE	TZ	JS	GI	idf	fpx	jwg	tlg
649	18	IV	II	V	15	23	26		EJ	OY	IV	AQ	KW	FX	MT	PS	LU	BD	lsa	[illegible]bw	vcj	rxn
649	17	I	IV	II	21	10	06		IR	KZ	LS	EM	OV	GY	QX	AF	JP	BU	mae	hzi	sog	ysi
649	16	V	II	III	08	16	13		HM	JO	DI	NR	BY	XZ	GS	PU	FQ	CT	tdp	dhb	fkb	uiv
649	15	II	IV	I	01	03	07		DS	HY	MR	GW	LX	AJ	BQ	CO	IP	NT	ldw	hzj	soh	wvg
649	14	IV	I	V	15	11	05	AI BT MV HU	GM	JR	KS	IY	HZ	PL	AX	BT	CQ	NV	imz	noa	tjv	xtk
649	13	I	III	II	13	20	03	FW EL DQ KN	LY	AG	KM	BR	IQ	JU	HV	SW	ET	CX	zgr	dgz	gjo	ryq
649	12	V	II	IV	18	10	07	RZ OQ CP SX	MU	BP	CY	RZ	KX	AN	JT	DG	IL	FW	zdy	rkf	tjw	xtl
649	11	II	IV	III	02	26	15		KN	UY	HR	PW	FM	BO	EZ	QT	DX	JV	zea	rjy	soi	wvh
649	10	III	V	IV	23	21	01		LR	IK	MS	QU	HW	PT	GO	VX	FZ	EN	lrc	zbx	vbm	rxo
649	9	V	I	III	16	04	08		QY	BS	LN	KT	AP	IU	DW	HO	RV	JZ	edj	eyr	vby	tlh
649	8	IV	II	V	13	19	25		FI	NQ	SY	CU	BZ	AH	EL	TX	DO	KP	yiz	dha	ekc	tli
649	7	I	IV	II	09	03	22		UX	IZ	HN	BK	GQ	CP	FT	JY	MW	AR	lan	dgb	zsj	wbi
649	6	III	I	V	11	18	14	IL AP EU HO	DQ	GU	BW	NP	HK	AZ	CI	PO	JX	VY	lao	cft	zsk	wbj
649	5	V	II	IV	23	02	25	QT WZ KV GM	MV	CL	GK	OQ	BI	FU	HS	PX	NW	EY	lju	cdr	iye	waj
649	4	II	IV	I	04	21	09	BF NR DX CS	AC	BL	OZ	EK	QW	GP	SU	DH	JM	TX	lsb	zby	vcy	ujb
649	3	V	I	II	19	11	06		KR	MP	CN	BF	EH	DZ	IW	AV	GJ	LO	lap	owd	iwu	wak
649	2	IV	V	I	16	14	02		BN	HU	EG	PY	KQ	CF	OS	JW	AI	VZ	aqd	bdy	iyf	xtd
649	1	II	I	III	23	12	10		DP	BM	NZ	CK	GV	HQ	AF	UY	SW	JO	kgl	cdf	giq	wuv

Symmetric Key Cryptography

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Problems: key distribution

Symmetric Key Cryptography

system	key	encryption	decryption
Ceasar			
Vigenère			
ADFGVX			
Enigma			

Symmetric Key Cryptography

system	key	encryption	decryption
Ceasar	shift	shift forward	shift backward
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Enigma			

Symmetric Key Cryptography

system	key	encryption	decryption
Ceasar	shift	shift forward	shift backward
Vigenère	sequence of shifts	shift forward	shift backward
ADFGVX	square & column order	complicated!	complicated backwards!
Enigma	machine setup	press key, read light	press key, read light

Security of a cryptosystem

The **keyspace** is the set of all possible secret keys.

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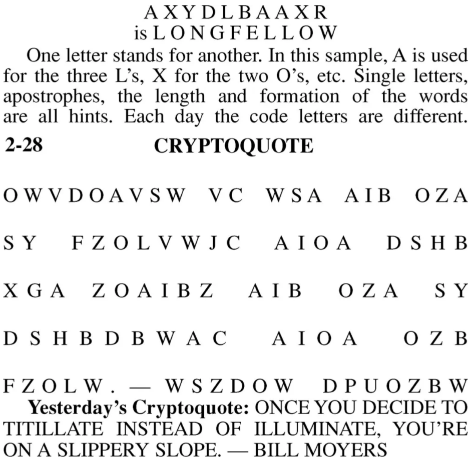
key	plaintext
0	WFYDAKZLWPL
1	XGZEBLAMXQM
2	YHAFCMBNYRN
3	ZIBGDNCOZSO
4	AJCHEODPATP
5	BKDIFPEQBUQ
6	CLEJGQFRCVR
7	DMFKHRGSDWS
8	ENGLISHTEXT
9	FOHMJTIUFYU
10	GPINKUJVGZV
11	HQJOLVKWHAW
12	IRKPMWLXIBX

key	plaintext
13	JSLQNXMYJCY
14	KTMROYNZKDZ
15	LUNSPZOALEA
16	MVOTQAPBMFB
17	NWPURBQCNGC
18	OXQVSCRDOHD
19	PYRWTDSEPIE
20	QZSXUETFQJF
21	RATYVFUGRKG
22	SBUZWGVHSLH
23	TCVAXHWITMI
24	UDWBYIXJUNJ
25	VEXCZJYKVOK

What's better than exhaustive search?



AXYDLBAAXR
is LONGFELLOW

One letter stands for another. In this sample, A is used for the three L's, X for the two O's, etc. Single letters, apostrophes, the length and formation of the words are all hints. Each day the code letters are different.

2-28 **CRYPTOQUOTE**

OWVDOAVSW VC WSA AIB OZA
SY FZOLVWJC AIOA DSHB
XGA ZOAIBZ AIB OZA SY
DSHBDBWAC AIOA OZB
FZOLW. — WSZDOW DPUOZBW

Yesterday's Cryptoquote: ONCE YOU DECIDE TO TITILLATE INSTEAD OF ILLUMINATE, YOU'RE ON A SLIPPERY SLOPE. — BILL MOYERS

Source: *www.dailyrepublic.com*

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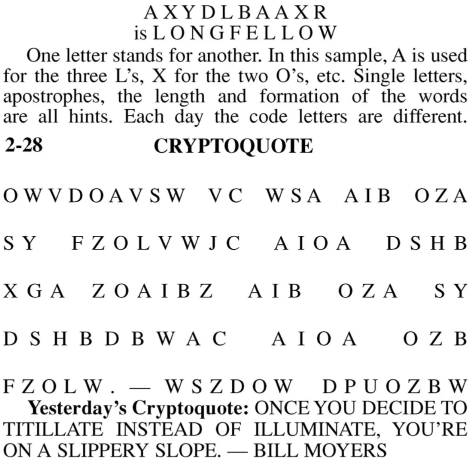

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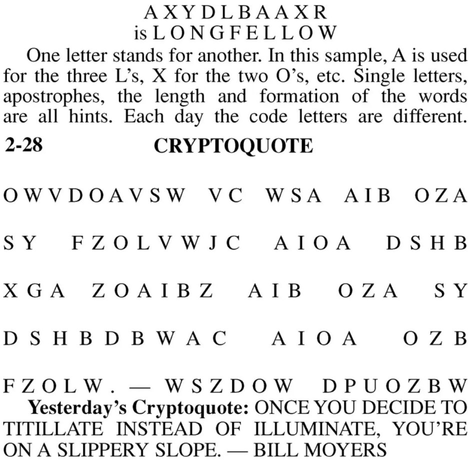

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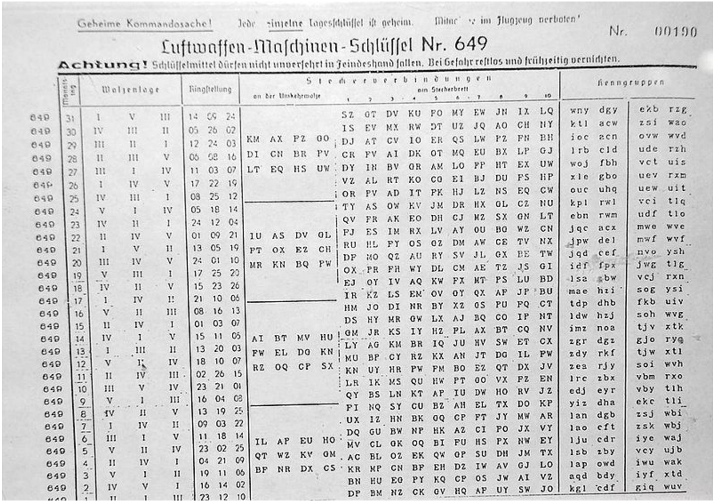
$> 400,000,000,000,000,000,000,000,000 = 4 \times 10^{26}$.

The enigma keyspace



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649	16	V	II	III	08	16	13		HM	JO	DI	NR	BY	XZ	GS	PU	FQ	CT	tdp	dhb	fkb	uiv
649	15	II	IV	I	01	03	07		DS	HY	MR	GW	LX	AJ	BQ	CO	IP	NT	ldw	hzj	soh	wvg
649	14	IV	I	V	15	11	05	AI BT MV HU	GM	JR	KS	IY	HZ	PL	AX	BT	CQ	NV	imz	noa	tjv	xtk
649	13	I	III	II	13	20	03	FW EL DG KN	LY	AG	KM	BR	IQ	JU	HV	SW	ET	CX	zgr	dgz	gjo	ryq
649	12	V	II	IV	18	10	07	RZ OQ CP SX	MU	BP	CY	RZ	KX	AN	JT	DG	IL	FW	zdy	rkf	tjw	xtl
649	11	II	IV	III	02	26	15		KN	UY	HR	PW	FM	BO	EZ	QT	DX	JV	zea	rjy	soi	wvh
649	10	III	V	IV	23	21	01		LR	IK	MS	QU	HW	PT	GO	VX	FZ	EN	lrc	zbx	vbm	rxo
649	9	V	I	III	16	04	08		QY	BS	LN	KT	AP	IU	DW	HO	RV	JZ	edj	eyr	vby	tlh
649	8	IV	II	V	13	19	25		FI	NQ	SY	CU	BZ	AH	EL	TX	DO	KP	yiz	dha	ekc	tli
649	7	I	IV	II	09	03	22		UX	IZ	HN	BK	GQ	CP	FT	JY	MW	AR	lan	dgb	zsj	wbi
649	6	III	I	V	11	18	14		DQ	GU	BW	NP	HK	AZ	CI	FO	JX	VY	lao	cft	zsk	wbj
649	5	V	II	IV	23	02	25	IL AP EU HO	MV	CL	GK	OQ	BI	FU	HS	PX	NW	EY	lju	cdr	iye	waj
649	4	II	IV	I	04	21	09	QT WZ KV GM	AC	BL	OZ	EK	QW	GP	SU	DH	JM	TX	lsb	zby	vcy	ujb
649	3	V	I	II	19	11	06	BF NR DX CS	KR	MP	CN	BF	EH	DZ	IW	AV	GJ	LO	lap	owd	iwu	wak
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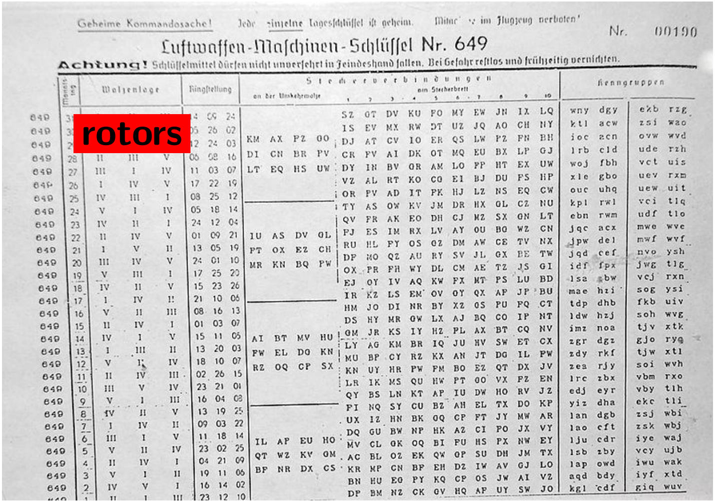

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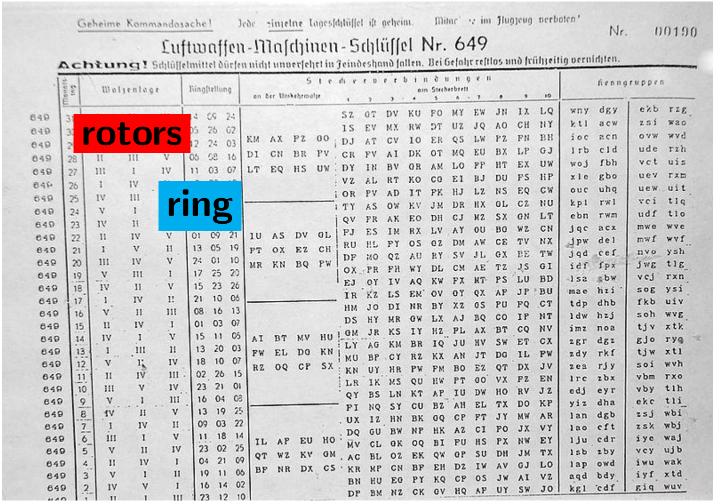
649	30	[illegible]	[illegible]	[illegible]	05	26	02		IS	EV	MX	RW	DT	UZ	JQ	AO	CH	NY	ktl	acw	zsi	wao
649	29	[illegible]	[illegible]	[illegible]	12	24	03	KM AX PZ OO	DJ	AT	CV	IO	ER	QS	LW	PZ	FN	BH	ioc	acn	ovw	wvd
649	28	II	III	V	06	08	16	DI CN BR PV	CR	FV	AI	DK	OT	MQ	EU	BX	LP	GJ	lrb	cld	ude	rzh
649	27	III	I	IV	11	03	07	LT EQ HS UW	DY	IN	BV	GR	AM	LO	FP	HT	EX	UW	woj	fbh	vct	uis
649	26	I	IV	V	17	22	19		VZ	AL	RT	KO	CG	EI	BJ	DU	FS	HP	xle	gbo	uev	rxm
649	25	IV	III	I	08	25	12		OR	PV	AD	IT	PK	HJ	LZ	NS	EQ	CW	ouc	uhq	uew	uit
649	24	V	I	IV	05	18	14		TY	AS	OW	KV	JM	DR	HX	GL	CZ	NU	kpl	rwl	vci	tlq
649	23	IV	II	I	24	12	04		QV	FR	AK	EO	DH	CJ	MZ	SX	GN	LT	ebn	rwm	udf	tlo
649	22	II	IV	V	01	09	21	IU AS DV GL	FJ	ES	IM	RX	LV	AY	OU	BG	WZ	CN	jqc	acx	mwe	wve
649	21	I	V	II	13	05	19	PT OX EZ CH	RU	HL	PY	OS	GZ	DM	AW	CE	TV	NX	jpw	del	mwf	wvf
649	20	III	IV	V	24	01	10	MR KN BQ PW	DF	MO	QZ	AU	RY	SV	JL	GX	BE	TW	jqd	cef	nvo	ysh
649	19	V	III	I	17	25	20		OX	PR	FH	WY	DL	CM	AE	TZ	JS	GI	idf	fpx	jwg	tlg
649	18	IV	II	V	15	23	26		EJ	OY	IV	AQ	KW	FX	MT	PS	LU	BD	lsa	[illegible]bw	vcj	rxn
649	17	I	IV	II	21	10	06		IR	KZ	LS	EM	OV	GY	QX	AP	JP	BU	mae	hzi	sog	ysi
649	16	V	II	III	08	16	13		HM	JO	DI	NR	BY	XZ	OS	PU	FQ	CT	tdp	dhb	fkb	uiv
649	15	II	IV	I	01	03	07		DS	HY	MR	GW	LX	AJ	BQ	CO	IP	NT	ldw	hzj	soh	wvg
649	14	IV	I	V	15	11	05	AI BT MV HU	GM	JR	KS	IY	HZ	PL	AX	BT	CQ	NV	imz	noa	tjv	xtk
649	13	I	III	II	13	20	03	FW EL DG KN	LY	AG	KM	BR	IQ	JU	HV	SW	ET	CX	zgr	dgz	gjo	ryq
649	12	V	II	IV	18	10	07	RZ OQ CP SX	MU	BP	CY	RZ	KX	AN	JT	DG	IL	PW	zdy	rkf	tjw	xtl
649	11	II	IV	III	02	26	15		KN	UY	HR	PW	FM	BO	EZ	QT	DX	JV	zea	rjy	soi	wvh
649	10	III	V	IV	23	21	01		LR	IK	MS	QU	HW	PT	GO	VX	FZ	EN	lrc	zbx	vbm	rxo
649	9	V	I	III	16	04	08		QY	BS	LN	KT	AP	IU	DW	HO	RV	JZ	edj	eyr	vby	tlh
649	8	IV	II	V	13	19	25		FI	NQ	SY	GU	BZ	AH	EL	TX	DO	KP	yiz	dha	ekc	tli
649	7	I	IV	II	09	03	22		UX	IZ	HN	BK	GQ	CP	FT	JY	MW	AR	lan	dgb	zsj	wbi
649	6	III	I	V	11	18	14		DQ	GU	BW	NP	HK	AZ	CI	PO	JX	VY	lao	cft	zsk	wbj
649	5	V	II	IV	23	02	25	IL AP EU HO	MV	CL	GK	OQ	BI	FU	HS	PX	NW	EY	lju	cdr	iye	waj
649	4	II	IV	I	04	21	09	QT WZ KV GM	AC	BL	OZ	EK	QW	OP	SU	DH	JM	TX	lsb	zby	vcy	ujb
649	3	V	I	II	19	11	06	BF NR DX CS	KR	MP	CN	BF	EH	DZ	IW	AV	GJ	LO	lap	owd	iwu	wak
649	2	IV	V	I	16	14	02		BN	HU	EG	PY	KQ	CP	OS	JW	AI	VZ	aqd	bdy	iyf	xtd
649	1	II	I	III	23	12	10		DP	BM	NZ	CK	GV	HQ	AF	UY	SW	JO	kgl	cdf	giq	wuv

rotors

$5 \cdot 4 \cdot 3$

The enigma keyspace



rotors
ring

Geheime Kommandoſache! Jede einzelne Tagesſchlüſſel iſt geheim. Mitnahme im Flugzeug verboten!

Nr. 00190

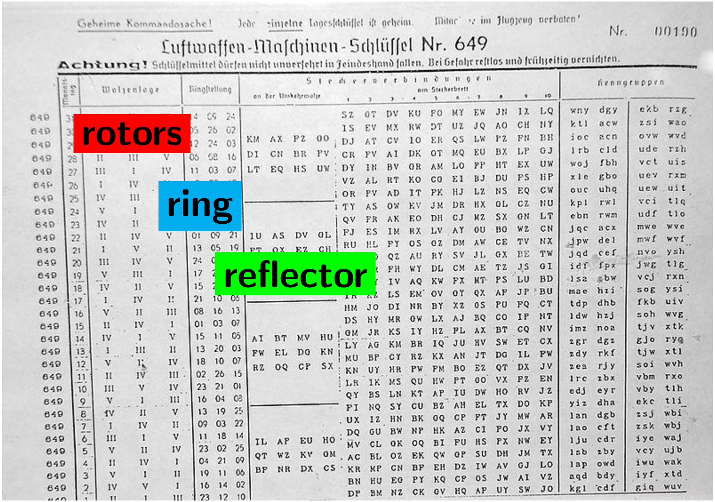
Luftwaffen-Maſchinen-Schlüſſel Nr. 649

Achtung! Schlüſſelmittel dürfen nicht unverſehrt in Feindeshand fallen. Bei Gefahr reſtlos und frühzeitig vernichten.

	Monatstag	Walzenlage			Ringſtellung			Steckerverbindungen an der Umkehrwalze	am Steckerbrett 1	2	3	4	5	6	7	8	9	10	Kenngruppen			
649	31				4	09	24		SZ	OT	DV	KU	FO	MY	EW	JN	IX	LQ	wny	dgy	ezb	rzg
649	30				5	26	02		IS	EV	MX	RW	DT	UZ	JQ	AO	CH	NY	ktl	acw	zsi	wao
649	29				12	24	03	KM AX PZ OO	DJ	AT	CV	IO	ER	QS	LW	PZ	FN	BH	ioc	acn	ovw	wvd
649	28	II	III	V	06	08	16	DI CN BR PV	CR	FV	AI	DK	OT	MQ	EU	BX	LP	GJ	lrb	cld	ude	rzh
649	27	III	I	IV	11	03	07	LT EQ HS UW	DY	IN	BV	OR	AM	LO	FP	HT	EX	UW	woj	fbh	vct	uis
649	26	I	IV						VZ	AL	RT	KO	CG	EI	BJ	DU	FS	HP	xle	gbo	uev	rxm
649	25	IV	III						OR	PV	AD	IT	PK	HJ	LZ	NS	EQ	CW	ouc	uhq	uew	uit
649	24	V	I						TY	AS	OW	KV	JM	DR	HX	GL	CZ	NU	kpl	rwl	vci	tlq
649	23	IV	II						QV	FR	AK	EO	DH	CJ	MZ	SX	GN	LT	ebn	rwm	udf	tlo
649	22	II	IV	V	01	09	21	IU AS DV GL	FJ	ES	IM	RX	LV	AY	OU	BG	WZ	CN	jqc	acx	mwe	wve
649	21	I	V	II	13	05	19	PT OX EZ CH	RU	HL	PY	OS	GZ	DM	AW	CE	TV	NX	jpw	del	mwf	wvf
649	20	III	IV	V	24	01	10	MR KN BQ PW	DF	MO	QZ	AU	RY	SV	JL	GX	BE	TW	jqd	cef	nvo	ysh
649	19	V	III	I	17	25	20		OX	PR	FH	WY	DL	CM	AE	TZ	JS	GI	idf	fpx	jwg	tlg
649	18	IV	II	V	15	23	26		EJ	OY	IV	AQ	KW	FX	MT	PS	LU	BD	lsa	gbw	vcj	rxn
649	17	I	IV	II	21	10	06		IR	KZ	LS	EM	OV	GY	QX	AP	JP	BU	mae	hzi	sog	ysi
649	16	V	II	III	08	16	13		HM	JO	DI	NR	BY	XZ	GS	PU	FQ	CT	tdp	dhb	fkb	uiv
649	15	II	IV	I	01	03	07		DS	HY	MR	GW	LX	AJ	BQ	CO	IP	NT	ldw	hzj	soh	wvg
649	14	IV	I	V	15	11	05	AI BT MV HU	GM	JR	KS	IY	HZ	PL	AX	BT	CQ	NV	imz	noa	tjv	xtk
649	13	I	III	II	13	20	03	FW EL DO KN	LY	AG	KM	BR	IQ	JU	HV	SW	ET	CX	zgr	dgz	gjo	ryq
649	12	V	II	IV	18	10	07	RZ OQ CP SX	MU	BP	CY	RZ	KX	AN	JT	DG	IL	PW	zdy	rkf	tjw	xtl
649	11	II	IV	III	02	26	15		KN	UY	HR	PW	FM	BO	EZ	QT	DX	JV	zea	rjy	soi	wvh
649	10	III	V	IV	23	21	01		LR	IK	MS	QU	HW	PT	GO	VX	FZ	EN	lrc	zbx	vbm	rxo
649	9	V	I	III	16	04	08		QY	BS	LN	KT	AP	IU	DW	HO	RV	JZ	edj	eyr	vby	tlh
649	8	IV	II	V	13	19	25		FI	NQ	SY	CU	BZ	AH	EL	TX	DO	KP	yiz	dha	ekc	tli
649	7	I	IV	II	09	03	22		UX	IZ	HN	BK	GQ	CP	FT	JY	MW	AR	lan	dgb	zsj	wbi
649	6	III	I	V	11	18	14		DQ	GU	BW	NP	HK	AZ	CI	PO	JX	VY	lao	cft	zsk	wbj
649	5	V	II	IV	23	02	25	IL AP EU HO	MV	CL	GK	OQ	BI	FU	HS	PX	NW	EY	lju	cdr	iye	waj
649	4	II	IV	I	04	21	09	QT WZ KV GM	AC	BL	OZ	EK	QW	GP	SU	DH	JM	TX	lsb	zby	vcy	ujb
649	3	V	I	II	19	11	06	BF NR DX CS	KR	MP	CN	BF	EH	DZ	IW	AV	GJ	LO	lap	owd	iwu	wak
649	2	IV	V	I	16	14	02		BN	HU	EG	PY	KQ	CP	OS	JW	AI	VZ	aqd	bdy	iyf	xtd
649	1	II	I	III	23	12	10		DP	BM	NZ	CK	GV	HQ	AF	UY	SW	JO	kgl	cdf	giq	wuv

$5 \cdot 4 \cdot 3 \cdot 26^3$

The enigma keyspace



Geheime Kommandosache! Jede einzelne Tagesſchlüſſel iſt geheim. Mitnahme im Flugzeug verboten! Nr. 00190

Luftwaffen-Maſchinen-Schlüſſel Nr. 649

Achtung! Schlüſſelmittel dürfen nicht unverſehrt in Feindeshand fallen. Bei Gefahr reſtlos und frühzeitig vernichten.

	Monatstag	Walzenlage			Ringſtellung			Steckerverbindungen														Kenngruppen			
								an der Umkehrwalze				am Steckerbrett 1	2	3	4	5	6	7	8	9	10				
649	31	[illegible]	[illegible]	[illegible]	[illegible]	09	24					SZ	GT	DV	KU	FO	MY	EW	JN	IX	LQ	wny	dgy	ezb	rzg
649	[illegible]	[illegible]	[illegible]	[illegible]	05	26	02					IS	EV	MX	RW	DT	UZ	JQ	AO	CH	NY	ktl	acw	zsi	wao
649	[illegible]	[illegible]	[illegible]	[illegible]	12	24	03	KM	AX	PZ	OO	DJ	AT	CV	IO	ER	QS	LW	PZ	FN	BH	ioc	acn	ovw	wvd
649	28	II	III	V	06	08	16	DI	CN	BR	PV	CR	FV	AI	DK	OT	MQ	EU	BX	LP	GJ	lrb	cld	ude	rzh
649	27	III	I	IV	11	03	07	LT	EQ	HS	UW	DY	IN	BV	GR	AM	LO	FP	HT	EX	UW	woj	fbh	vct	uis
649	26	I	IV	[illegible]	[illegible]	[illegible]	[illegible]					VZ	AL	RT	KO	CG	EI	BJ	DU	FS	HP	xle	gbo	uev	rxm
649	25	IV	III	[illegible]	[illegible]	[illegible]	[illegible]					OR	PV	AD	IT	PK	HJ	LZ	NS	EQ	CW	ouc	uhq	uew	uit
649	24	V	I	[illegible]	[illegible]	[illegible]	[illegible]					TY	AS	OW	KV	JM	DR	HX	GL	CZ	NU	kpl	rwl	vci	tlq
649	23	IV	II	[illegible]	[illegible]	[illegible]	[illegible]					QV	FR	AK	EO	DH	CJ	MZ	SX	GN	LT	ebn	rwm	udf	tlo
649	22	II	IV	V	01	09	21	IU	AS	DV	GL	FJ	ES	IM	RX	LV	AY	OU	BG	WZ	CN	jqc	acx	mwe	wve
649	21	I	V	II	13	05	19	PT	OX	EZ	CH	RU	HL	FY	OS	GZ	DM	AW	CE	TV	NX	jpw	del	mwf	wvf
649	20	III	IV	V	24	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	QZ	AU	RY	SV	JL	GX	BE	TW	jqd	cef	nvo	ysh
649	19	V	III	I	17	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	FH	WY	DL	CM	AE	TZ	JS	GI	idf	fpx	jwg	tlg
649	18	IV	II	V	15	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	IV	AQ	KW	FX	MT	PS	LU	BD	lsa	gbw	vcj	rxn
649	17	I	IV	II	21	10	06					IR	KE	LS	EM	OV	OY	QX	AP	JP	BU	mae	hzi	sog	ysi
649	16	V	II	III	08	16	13					HM	JO	DI	NR	BY	XZ	GS	PU	FQ	CT	tdp	dhb	fkb	uiv
649	15	II	IV	I	01	03	07					DS	HY	MR	GW	LX	AJ	BQ	CO	IP	NT	ldw	hzj	soh	wvg
649	14	IV	I	V	15	11	05	AI	BT	MV	HU	GM	JR	KS	IY	HZ	PL	AX	BT	CQ	NV	imz	noa	tjv	xtk
649	13	I	III	II	13	20	03	FW	EL	DO	KN	LY	AG	KM	BR	IQ	JU	HV	SW	ET	CX	zgr	dgz	gjo	ryq
649	12	V	II	IV	18	10	07	RZ	OQ	CP	SX	MU	BP	CY	RZ	KX	AN	JT	DG	IL	FW	zdy	rkf	tjw	xtl
649	11	II	IV	III	02	26	15					KN	UY	HR	PW	FM	BO	EZ	QT	DX	JV	zea	rjy	soi	wvh
649	10	III	V	IV	23	21	01					LR	IK	MS	QU	HW	PT	GO	VX	FZ	EN	lrc	zbx	vbm	rxo
649	9	V	I	III	16	04	08					QY	BS	LN	KT	AP	IU	DW	HO	RV	JZ	edj	eyr	vby	tlh
649	8	IV	II	V	13	19	25					FI	NQ	SY	CU	BZ	AH	EL	TX	DO	KP	yiz	dha	ekc	tli
649	7	I	IV	II	09	03	22					UX	IZ	HN	BK	GQ	CP	FT	JY	MW	AR	lan	dgb	zsj	wbi
649	6	III	I	V	11	18	14					DQ	GU	BW	NP	HK	AZ	CI	PO	JX	VY	lao	cft	zsk	wbj
649	5	V	II	IV	23	02	25	IL	AP	EU	HO	MV	CL	GK	OQ	BI	FU	HS	PX	NW	EY	lju	cdr	iye	waj
649	4	II	IV	I	04	21	09	QT	WZ	KV	GM	AC	BL	OZ	EK	QW	GP	SU	DH	JM	TX	lsb	zby	vcy	ujb
649	3	V	I	II	19	11	06	BF	NR	DX	CS	KR	MP	CN	BF	EH	DZ	IW	AV	GJ	LO	lap	owd	iwu	wak
649	2	IV	V	I	16	14	02					BN	HU	EG	PY	KQ	CP	OS	JW	AI	VZ	aqd	bdy	iyf	xtd
649	1	II	I	III	23	12	10					DP	BM	NZ	CK	GV	HQ	AF	UY	SW	JO	kgl	cdf	giq	wuv

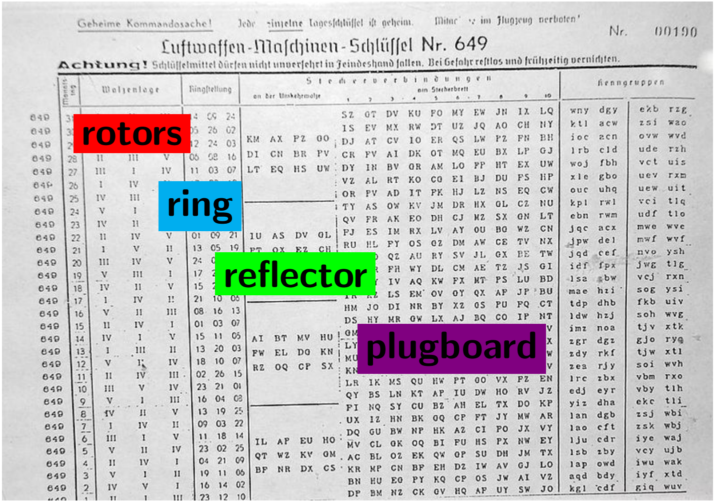
rotors

ring

reflector

$$5 \cdot 4 \cdot 3 \cdot 26^3 \cdot 24!/(12!2^{12})$$

The enigma keyspace



Geheime Kommandosache! Jede einzelne Tagesſchlüſſel iſt geheim. Mitnahme im Flugzeug verboten! Nr. 00190

Luftwaffen-Maſchinen-Schlüſſel Nr. 649

Achtung! Schlüſſelmittel dürfen nicht unverſehrt in Feindeshand fallen. Bei Gefahr reſtlos und frühzeitig vernichten.

	Monatstag	Walzenlage			Ringſtellung			Steckerverbindungen														Kenngruppen			
								an der Umkehrwalze				am Steckerbrett													
												1	2	3	4	5	6	7	8	9	10				
649	31	[illegible]	[illegible]	[illegible]	[illegible]	09	24					SZ	OT	DV	KU	PO	MY	EW	JN	IX	LQ	wny	dgy	ezb	rzg
649	30	[illegible]	[illegible]	[illegible]	05	26	02					IS	EV	MX	RW	DT	UZ	JQ	AO	CH	NY	ktl	acw	zsi	wao
649	29	[illegible]	[illegible]	[illegible]	12	24	03	KM	AX	PZ	OO	DJ	AT	CV	IO	ER	QS	LW	PZ	FN	BH	ioc	acn	ovw	wvd
649	28	II	III	V	06	08	16	DI	CN	BR	PV	CR	PV	AI	DK	OT	MQ	EU	BX	LP	GJ	lrb	cld	ude	rzh
649	27	III	I	IV	11	03	07	LT	EQ	HS	UW	DY	IN	BV	OR	AM	LO	PP	HT	EX	UW	woj	fbh	vct	uis
649	26	I	IV	[illegible]	[illegible]	[illegible]	[illegible]					VZ	AL	RT	KO	CO	EI	BJ	DU	PS	HP	xle	gbo	uev	rxm
649	25	IV	III	[illegible]	[illegible]	[illegible]	[illegible]					OR	PV	AD	IT	PK	HJ	LZ	NS	EQ	CW	ouc	uhq	uew	uit
649	24	V	I	[illegible]	[illegible]	[illegible]	[illegible]					TY	AS	OW	KV	JM	DR	HX	GL	CZ	NU	kpl	rwl	vci	tlq
649	23	IV	II	[illegible]	[illegible]	[illegible]	[illegible]					QV	FR	AK	EO	DH	CJ	MZ	SX	GN	LT	ebn	rwm	udf	tlo
649	22	II	IV	V	01	09	21	IU	AS	DV	GL	PJ	ES	IM	RX	LV	AY	OU	BO	WZ	CN	jqc	acx	mwe	wve
649	21	I	V	II	13	05	19	PT	OX	EZ	CH	RU	HL	PY	OS	GZ	DM	AW	CE	TV	NX	jpw	del	mwf	wvf
649	20	III	IV	V	24	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	QZ	AU	RY	SV	JL	GX	BE	TW	jqd	cef	nvo	ysh
649	19	V	III	I	17	[illegible]	[illegible]					[illegible]	[illegible]	FH	WY	DL	CM	AE	TZ	JS	GI	idf	fpx	jwg	tlg
649	18	IV	II	V	15	[illegible]	[illegible]					[illegible]	[illegible]	IV	AQ	KW	FX	MT	PS	LU	BD	lsa	[illegible]bw	vcj	rxn
649	17	I	IV	II	21	10	06					[illegible]	[illegible]	LS	EN	OV	OY	QX	AP	JP	BU	mae	hzi	sog	ysi
649	16	V	II	III	08	16	13					HM	JO	DI	NR	BY	XZ	OS	PU	PQ	CT	tdp	dhb	fkb	uiv
649	15	II	IV	I	01	03	07					DS	HY	MR	OW	LX	AJ	BQ	CO	IP	NT	ldw	hzj	soh	wvg
649	14	IV	I	V	15	11	05	AI	BT	MV	HU	GM	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	imz	noa	tjv	xtk
649	13	I	III	II	13	20	03	FW	EL	DO	KN	LY	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	zgr	dgz	gjo	ryq
649	12	V	II	IV	18	10	07	RZ	OQ	CP	SX	MU	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	zdy	rkf	tjw	xtl
649	11	II	IV	III	02	26	15					KN	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	zea	rjy	soi	wvh
649	10	III	V	IV	23	21	01					LR	IK	MS	QU	HW	PT	GO	VX	PZ	EN	lrc	zbx	vbm	rxo
649	9	V	I	III	16	04	08					QY	BS	LN	KT	AP	IU	DW	HO	RV	JZ	edj	eyr	vby	tlh
649	8	IV	II	V	13	19	25					FI	NQ	SY	CU	BZ	AH	EL	TX	DO	KP	yiz	dha	ekc	tli
649	7	I	IV	II	09	03	22					UX	IZ	HN	BK	OQ	CP	FT	JY	MW	AR	lan	dgb	zsj	wbi
649	6	III	I	V	11	18	14	IL	AP	EU	HO	DQ	GU	BW	NP	HK	AZ	CI	PO	JX	VY	lao	cft	zsk	wbj
649	5	V	II	IV	23	02	25	QT	WZ	KV	GM	MV	CL	OK	OQ	BI	FU	HS	PX	NW	EY	lju	cdr	iye	waj
649	4	II	IV	I	04	21	09	BF	NR	DX	CS	AC	BL	OZ	EK	QW	OP	SU	DH	JM	TX	lsb	zby	vcy	ujb
649	3	V	I	II	19	11	06					KR	MP	CN	BF	EH	DZ	IW	AV	GJ	LO	lap	owd	iwu	wak
649	2	IV	V	I	16	14	02					BN	HU	EG	PY	KQ	CP	OS	JW	AI	VZ	aqd	bdy	iyf	xtd
649	1	II	I	III	23	12	10					DP	BM	NZ	CK	GV	HQ	AP	UY	SW	JO	kgl	cdf	giq	wuv

rotors

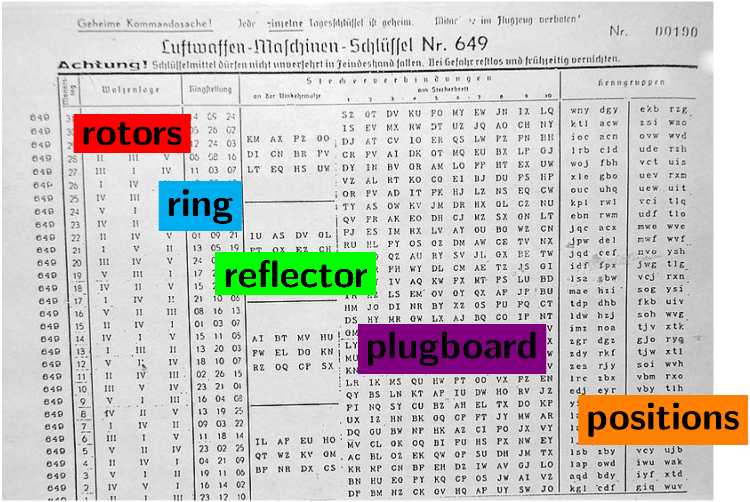
ring

reflector

plugboard

$$5 \cdot 4 \cdot 3 \cdot 26^3 \cdot 24!/(12!2^{12}) \cdot 26!/(10!6!2^{10})$$

The enigma keyspace



Geheime Kommandosache! Jede einzelne Tagesſchlüſſel iſt geheim. Mitnahme im Flugzeug verboten!

Nr. 00190

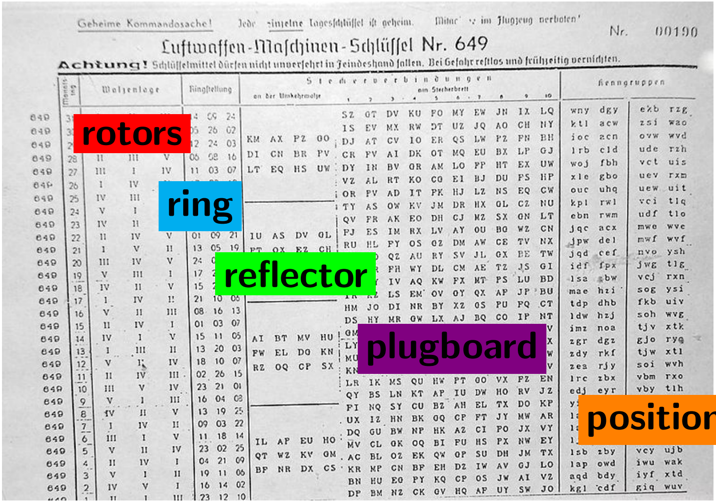
Luftwaffen-Maſchinen-Schlüſſel Nr. 649

Achtung! Schlüſſelmittel dürfen nicht unverſehrt in Feindeshand fallen. Bei Gefahr reſtlos und frühzeitig vernichten.

Monatstag | Walzenlage | Ringſtellung | Steckerverbindungen an der Umkehrwalze | am Steckerbrett 1 2 3 4 5 6 7 8 9 10 | Kenngruppen

$$5 \cdot 4 \cdot 3 \cdot 26^3 \cdot 24!/(12!2^{12}) \cdot 26!/(10!6!2^{10}) \cdot 26^3$$

The enigma keyspace


rotors
ring
reflector
plugboard
positions

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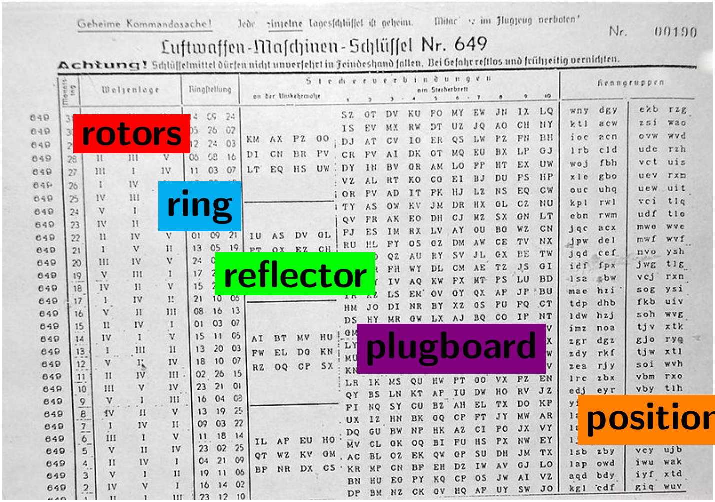
	Monatstag	Walzenlage			Ringſtellung			Steckerverbindungen an der Umkehrwalze	am Steckerbrett 1	2	3	4	5	6	7	8	9	10	Kenngruppen			
649	31	[illegible]	[illegible]	[illegible]	[illegible]	09	24		SZ	GT	DV	KU	FO	MY	EW	JN	IX	LQ	wny	dgy	ezb	rzg
649	30	[illegible]	[illegible]	[illegible]	05	26	02		IS	EV	MX	RW	DT	UZ	JQ	AO	CH	NY	ktl	acw	zsi	wao
649	29	[illegible]	[illegible]	[illegible]	12	24	03	KM AX PZ GO	DJ	AT	CV	IO	ER	QS	LW	PZ	FN	BH	ioc	acn	ovw	wvd
649	28	II	III	V	06	08	16	DI CN BR PV	CR	FV	AI	DK	OT	MQ	EU	BX	LP	GJ	lrb	cld	ude	rzh
649	27	III	I	IV	11	03	07	LT EQ HS UW	DY	IN	BV	GR	AM	LO	PP	HT	EX	UW	woj	fbh	vct	uis
649	26	I	IV	[illegible]	[illegible]	[illegible]	[illegible]		VZ	AL	RT	KO	CG	EI	BJ	DU	FS	HP	xle	gbo	uev	rxm
649	25	IV	III	[illegible]	[illegible]	[illegible]	[illegible]		OR	PV	AD	IT	PK	HJ	LZ	NS	EQ	CW	ouc	uhq	uew	uit
649	24	V	I	[illegible]	[illegible]	[illegible]	[illegible]		TY	AS	OW	KV	JM	DR	HX	GL	CZ	NU	kpl	rwl	vci	tlq
649	23	IV	II	[illegible]	[illegible]	[illegible]	[illegible]		QV	FR	AK	EO	DH	CJ	MZ	SX	GN	LT	ebn	rwm	udf	tlo
649	22	II	IV	V	01	09	21	IU AS DV GL	FJ	ES	IM	RX	LV	AY	OU	BG	WZ	CN	jqc	acx	mwe	wve
649	21	I	V	II	13	05	19	PT OX EZ CH	RU	HL	FY	OS	GZ	DM	AW	CE	TV	NX	jpw	del	mwf	wvf
649	20	III	IV	V	24	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	QZ	AU	RY	SV	JL	GX	BE	TW	jqd	cef	nvo	ysh
649	19	V	III	I	17	[illegible]	[illegible]		[illegible]	[illegible]	FH	WY	DL	CM	AE	TZ	JS	GI	idf	fpx	jwg	tlg
649	18	IV	II	V	15	[illegible]	[illegible]		[illegible]	[illegible]	IV	AQ	KW	FX	MT	PS	LU	BD	lsa	[illegible]	vcj	rxn
649	17	I	IV	II	21	10	06		[illegible]	[illegible]	LS	EM	OV	GY	QX	AP	JP	BU	mae	hzi	sog	ysi
649	16	V	II	III	08	16	13		HM	JO	DI	NR	BY	XZ	OS	PU	FQ	CT	tdp	dhb	fkb	uiv
649	15	II	IV	I	01	03	07		DS	HY	MR	GW	LX	AJ	BQ	CO	IP	NT	ldw	hzj	soh	wvg
649	14	IV	I	V	15	11	05	AI BT MV HU	GM	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	V	imz	noa	tjv	xtk
649	13	I	III	II	13	20	03	FW EL DG KN	LY	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	X	zgr	dgz	gjo	ryq
649	12	V	II	IV	18	10	07	RZ OQ CP SX	MU	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	W	zdy	rkf	tjw	xtl
649	11	II	IV	III	02	26	15		KN	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	V	zea	rjy	soi	wvh
649	10	III	V	IV	23	21	01		LR	IK	MS	QU	HW	PT	GO	VX	PZ	EN	lrc	zbx	vbm	rxo
649	9	V	I	III	16	04	08		QY	BS	LN	KT	AP	IU	DW	HO	RV	JZ	edj	eyr	vby	tlh
649	8	IV	II	V	13	19	25		FI	NQ	SY	CU	BZ	AH	EL	TX	DO	KP	[illegible]	[illegible]	[illegible]	[illegible]
649	7	I	IV	II	09	03	22		UX	IZ	HN	BK	GQ	CP	FT	JY	MW	AR	[illegible]	[illegible]	[illegible]	[illegible]
649	6	III	I	V	11	18	14		DQ	GU	BW	NP	HK	AZ	CI	PO	JX	VY	[illegible]	[illegible]	[illegible]	[illegible]
649	5	V	II	IV	23	02	25	IL AP EU HO	MV	CL	GK	OQ	BI	FU	HS	PX	NW	EY	[illegible]	[illegible]	[illegible]	[illegible]
649	4	II	IV	I	04	21	09	QT WZ KV GM	AC	BL	OZ	EK	QW	GP	SU	DH	JM	TX	lsb	zby	vcy	ujb
649	3	V	I	II	19	11	06	BF NR DX CS	KR	MP	CN	BF	EH	DZ	IW	AV	GJ	LO	lap	owd	iwu	wak
649	2	IV	V	I	16	14	02		BN	HU	EG	PY	KQ	CP	OS	JW	AI	VZ	aqd	bdy	iyf	xtd
649	1	II	I	III	23	12	10		DP	BM	NZ	CK	GV	HQ	AF	UY	SW	JO	kgl	cdf	giq	wuv

$5 \cdot 4 \cdot 3 \cdot 26^3 \cdot 24!/(12!2^{12}) \cdot 26!/(10!6!2^{10}) \cdot 26^3 \simeq 150$ undecillion

The enigma keyspace



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	Monatstag	Walzenlage			Ringſtellung			Steckerverbindungen											Kenngruppen			
								an der Umkehrwalze	am Steckerbrett													
									1	2	3	4	5	6	7	8	9	10				
649	31	[illegible]	[illegible]	[illegible]	14	09	24		SZ	OT	DV	KU	FO	MY	EW	JN	IX	LQ	wny	dgy	ezb	rzg
649	30	[illegible]	[illegible]	[illegible]	05	26	02		IS	EV	MX	RW	DT	UZ	JQ	AO	CH	NY	ktl	acw	zsi	wao
649	29	[illegible]	[illegible]	[illegible]	12	24	03	KM AX PZ OO	DJ	AT	CV	IO	ER	QS	LW	PZ	FN	BH	ioc	acn	ovw	wvd
649	28	II	III	V	06	08	16	DI CN BR PV	CR	FV	AI	DK	OT	MQ	EU	BX	LP	GJ	lrb	cld	ude	rzh
649	27	III	I	IV	11	03	07	LT EQ HS UW	DY	IN	BV	GR	AM	LO	FP	HT	EX	UW	woj	fbh	vct	uis
649	26	I	IV	[illegible]	[illegible]	[illegible]	[illegible]		VZ	AL	RT	KO	CG	EI	BJ	DU	FS	HP	xle	gbo	uev	rxm
649	25	IV	III	[illegible]	[illegible]	[illegible]	[illegible]		OR	PV	AD	IT	PK	HJ	LZ	NS	EQ	CW	ouc	uhq	uew	uit
649	24	V	I	[illegible]	[illegible]	[illegible]	[illegible]		TY	AS	OW	KV	JM	DR	HX	GL	CZ	NU	kpl	rwl	vci	tlq
649	23	IV	II	[illegible]	[illegible]	[illegible]	[illegible]		QV	FR	AK	EO	DH	CJ	MZ	SX	GN	LT	ebn	rwm	udf	tlo
649	22	II	IV	V	01	09	21	IU AS DV GL	FJ	ES	IM	RX	LV	AY	OU	BG	WZ	CN	jqc	acx	mwe	wve
649	21	I	V	II	13	05	19	PT OX EZ CH	RU	HL	FY	OS	GZ	DM	AW	CE	TV	NX	jpw	del	mwf	wvf
649	20	III	IV	V	24	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	QZ	AU	RY	SV	JL	GX	BE	TW	jqd	cef	nvo	ysh
649	19	V	III	I	17	[illegible]	[illegible]		[illegible]	[illegible]	FH	WY	DL	CM	AE	TZ	JS	GI	idf	fpx	jwg	tlg
649	18	IV	II	V	15	[illegible]	[illegible]		[illegible]	[illegible]	IV	AQ	KW	FX	MT	PS	LU	BD	lsa	gbw	vcj	rxn
649	17	I	IV	II	21	10	06		[illegible]	[illegible]	LS	EN	OV	OY	QX	AP	JP	BU	mae	hzi	sog	ysi
649	16	V	II	III	08	16	13		HM	JO	DI	NR	BY	XZ	OS	PU	FQ	CT	tdp	dhb	fkb	uiv
649	15	II	IV	I	01	03	07		DS	HY	MR	GW	LX	AJ	BQ	CO	IP	NT	ldw	hzj	soh	wvg
649	14	IV	I	V	15	11	05	AI BT MV HU	GM	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	imz	noa	tjv	xtk
649	13	I	III	II	13	20	03	FW EL DO KN	LY	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	zgr	dgz	gjo	ryq
649	12	V	II	IV	18	10	07	RZ OQ CP SX	MU	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	zdy	rkf	tjw	xtl
649	11	II	IV	III	02	26	15		KN	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	zea	rjy	soi	wvh
649	10	III	V	IV	23	21	01		LR	IK	MS	QU	HW	PT	GO	VX	FZ	EN	lrc	zbx	vbm	rxo
649	9	V	I	III	16	04	08		QY	BS	LN	KT	AP	IU	DW	HO	RV	JZ	edj	eyr	vby	tlh
649	8	IV	II	V	13	19	25		FI	NQ	SY	CU	BZ	AH	EL	TX	DO	KP	[illegible]	[illegible]	[illegible]	[illegible]
649	7	I	IV	II	09	03	22		UX	IZ	HN	BK	GQ	CF	FT	JY	MW	AR	[illegible]	[illegible]	[illegible]	[illegible]
649	6	III	I	V	11	18	14	IL AP EU HO	DQ	GU	BW	NP	HK	AZ	CI	PO	JX	VY	[illegible]	[illegible]	[illegible]	[illegible]
649	5	V	II	IV	23	02	25	QT WZ KV GM	MV	CL	GK	OQ	BI	FU	HS	PX	NW	EY	[illegible]	[illegible]	[illegible]	[illegible]
649	4	II	IV	I	04	21	09	BF NR DX CS	AC	BL	OZ	EK	QW	GP	SU	DH	JM	TX	lsb	zby	vcy	ujb
649	3	V	I	II	19	11	06		KR	MP	CN	BF	EH	DZ	IW	AV	GJ	LO	lap	owd	iwu	wak
649	2	IV	V	I	16	14	02		BN	HU	EG	PY	KQ	CP	OS	JW	AI	VZ	aqd	bdy	iyf	xtd
649	1	II	I	III	23	12	10		DP	BM	NZ	CK	GV	HQ	AF	UY	SW	JO	kgl	cdf	giq	wuv

rotors

ring

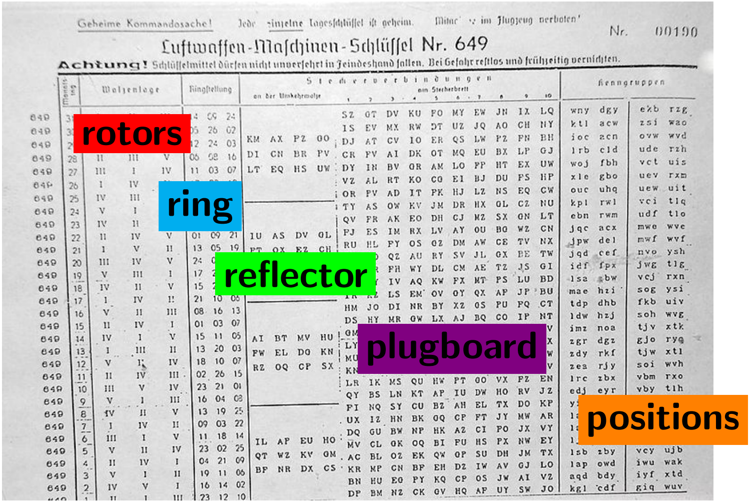
reflector

plugboard

positions

$5 \cdot 4 \cdot 3 \cdot 26^3 \cdot 24!/(12!2^{12}) \cdot 26!/(10!6!2^{10}) \cdot 26^3 \simeq$ 150 undecillion 789 decillion

The enigma keyspace


rotors
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	Monats-tag	Walzenlage			Ringſtellung			Steckerverbindungen an der Umkehrwalze				am Steckerbrett 1	2	3	4	5	6	7	8	9	10	Kenngruppen			
649	31	[illegible]	[illegible]	[illegible]	[illegible]	09	24					SZ	OT	DV	KU	FO	MY	EW	JN	IX	LQ	wny	dgy	ezb	rzg
649	30	[illegible]	[illegible]	[illegible]	05	26	02					IS	EV	MX	RW	DT	UZ	JQ	AO	CH	NY	ktl	acw	zsi	wao
649	29	[illegible]	[illegible]	[illegible]	12	24	03	KM	AX	PZ	OO	DJ	AT	CV	IO	ER	QS	LW	PZ	FN	BH	ioc	acn	ovw	wvd
649	28	II	III	V	06	08	16	DI	CN	BR	PV	CR	FV	AI	DK	OT	MQ	EU	BX	LP	GJ	lrb	cld	ude	rzh
649	27	III	I	IV	11	03	07	LT	EQ	HS	UW	DY	IN	BV	GR	AM	LO	PP	HT	EX	UW	woj	fbh	vct	uis
649	26	I	IV	[illegible]	[illegible]	[illegible]	[illegible]					VZ	AL	RT	KO	CG	EI	BJ	DU	FS	HP	xle	gbo	uev	rxm
649	25	IV	III	[illegible]	[illegible]	[illegible]	[illegible]					OR	PV	AD	IT	PK	HJ	LZ	NS	EQ	CW	ouc	uhq	uew	uit
649	24	V	I	[illegible]	[illegible]	[illegible]	[illegible]					TY	AS	OW	KV	JM	DR	HX	GL	CZ	NU	kpl	rwl	vci	tlq
649	23	IV	II	[illegible]	[illegible]	[illegible]	[illegible]					QV	FR	AK	EO	DH	CJ	MZ	SX	GN	LT	ebn	rwm	udf	tlo
649	22	II	IV	V	01	09	21	IU	AS	DV	GL	PJ	ES	IM	RX	LV	AY	OU	BG	WZ	CN	jqc	acx	mwe	wve
649	21	I	V	II	13	05	19	PT	OX	EZ	CH	RU	HL	FY	OS	GZ	DM	AW	CE	TV	NX	jpw	del	mwf	wvf
649	20	III	IV	V	24	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	QZ	AU	RY	SV	JL	GX	BE	TW	jqd	cef	nvo	ysh
649	19	V	III	I	17	[illegible]	[illegible]					[illegible]	[illegible]	FH	WY	DL	CM	AE	TZ	JS	GI	idf	fpx	jwg	tlg
649	18	IV	II	V	15	[illegible]	[illegible]					[illegible]	[illegible]	IV	AQ	KW	FX	MT	PS	LU	BD	lsa	gbw	vcj	rxn
649	17	I	IV	II	21	10	06					[illegible]	[illegible]	LS	EN	OV	OY	QX	AF	JP	BU	mae	hzi	sog	ysi
649	16	V	II	III	08	16	13					HM	JO	DI	NR	BY	XZ	OS	PU	FQ	CT	tdp	dhb	fkb	uiv
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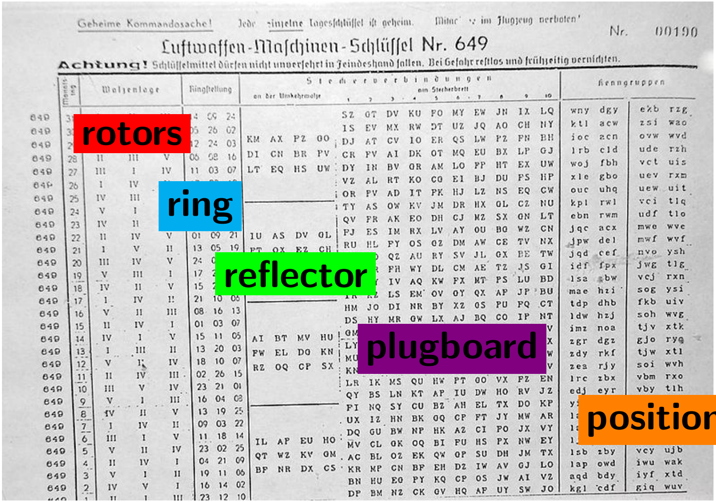
649	14	IV	I	V	15	11	05	AI	BT	MV	HU	GM	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	V	imz	noa	tjv	xtk
649	13	I	III	II	13	20	03	FW	EL	DO	KN	LY	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	X	zgr	dgz	gjo	ryq
649	12	V	I	IV	18	10	07	RZ	OQ	CP	SX	MU	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	W	zdy	rkf	tjw	xtl
649	11	II	IV	III	02	26	15					KN	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	V	zea	rjy	soi	wvh
649	10	III	V	IV	23	21	01					LR	IK	MS	QU	HW	PT	GO	VX	FZ	EN	lrc	zbx	vbm	rxo
649	9	V	I	III	16	04	08					QY	BS	LN	KT	AP	IU	DW	HO	RV	JZ	edj	eyr	vby	tlh
649	8	IV	II	V	13	19	25					FI	NQ	SY	CU	BZ	AH	EL	TX	DO	KP	[illegible]	[illegible]	[illegible]	[illegible]
649	7	I	IV	II	09	03	22					UX	IZ	HN	BK	GQ	CP	FT	JY	MW	AR	[illegible]	[illegible]	[illegible]	[illegible]
649	6	III	I	V	11	18	14					DQ	GU	BW	NP	HK	AZ	CI	PO	JX	VY	[illegible]	[illegible]	[illegible]	[illegible]
649	5	V	II	IV	23	02	25	IL	AP	EU	HO	MV	CL	OK	OQ	BI	FU	HS	PX	NW	EY	[illegible]	[illegible]	[illegible]	[illegible]
649	4	II	IV	I	04	21	09	QT	WZ	KV	GM	AC	BL	OZ	EK	QW	OP	SU	DH	JM	TX	lsb	zby	vcy	ujb
649	3	V	I	II	19	11	06	BF	NR	DX	CS	KR	MP	CN	BF	EH	DZ	IW	AV	GJ	LO	lap	owd	iwu	wak
649	2	IV	V	I	16	14	02					BN	HU	EG	PY	KQ	CP	OS	JW	AI	VZ	aqd	bdy	iyf	xtd
649	1	II	I	III	23	12	10					DP	BM	NZ	CK	GV	HQ	AF	UY	SW	JO	kgl	cdf	giq	wuv

$5 \cdot 4 \cdot 3 \cdot 26^3 \cdot 24!/(12!2^{12}) \cdot 26!/(10!6!2^{10}) \cdot 26^3 \quad \simeq$ 150 undecillion 789 decillion 931 nonillion

The enigma keyspace



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	Monatstag	Walzenlage			Ringſtellung			Steckerverbindungen														Kenngruppen			
								an der Umkehrwalze				am Steckerbrett 1	2	3	4	5	6	7	8	9	10				
649	31	[illegible]	[illegible]	[illegible]	[illegible]	09	24					SZ	OT	DV	KU	FO	MY	EW	JN	IX	LQ	wny	dgy	ezb	rzg
649	30	[illegible]	[illegible]	[illegible]	05	26	02					IS	EV	MX	RW	DT	UZ	JQ	AO	CH	NY	ktl	acw	zsi	wao
649	29	[illegible]	[illegible]	[illegible]	12	24	03	KM	AX	PZ	GO	DJ	AT	CV	IO	ER	QS	LW	PZ	FN	BH	joc	acn	ovw	wvd
649	28	II	III	V	06	08	16	DI	CN	BR	PV	CR	PV	AI	DK	OT	MQ	EU	BX	LP	GJ	lrb	cld	ude	rzh
649	27	III	I	IV	11	03	07	LT	EQ	HS	UW	DY	IN	BV	OR	AM	LO	FP	HT	EX	UW	woj	fbh	vct	uis
649	26	I	IV	[illegible]	[illegible]	[illegible]	[illegible]					VZ	AL	RT	KO	CG	EI	BJ	DU	FS	HP	xle	gbo	uev	rxm
649	25	IV	III	[illegible]	[illegible]	[illegible]	[illegible]					OR	PV	AD	IT	PK	HJ	LZ	NS	EQ	CW	ouc	uhq	uew	uit
649	24	V	I	[illegible]	[illegible]	[illegible]	[illegible]					TY	AS	OW	KV	JM	DR	HX	GL	CZ	NU	kpl	rwl	vci	tlq
649	23	IV	II	[illegible]	[illegible]	[illegible]	[illegible]					QV	FR	AK	EO	DH	CJ	MZ	SX	GN	LT	ebn	rwm	udf	tlo
649	22	II	IV	V	01	09	21	IU	AS	DV	GL	PJ	ES	IM	RX	LV	AY	OU	BG	WZ	CN	jqc	acx	mwe	wve
649	21	I	V	II	13	05	19	PT	OX	EZ	CH	RU	HL	PY	OS	GZ	DM	AW	CE	TV	NX	jpw	del	mwf	wvf
649	20	III	IV	V	24	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	QZ	AU	RY	SV	JL	GX	BE	TW	jqd	cef	nvo	ysh
649	19	V	III	I	17	[illegible]	[illegible]					[illegible]	[illegible]	FH	WY	DL	CM	AE	TZ	JS	GI	idf	fpx	jwg	tlg
649	18	IV	II	V	15	[illegible]	[illegible]					[illegible]	[illegible]	IV	AQ	KW	FX	MT	PS	LU	BD	lsa	gbw	vcj	rxn
649	17	I	IV	II	21	10	06					[illegible]	[illegible]	LS	EM	OV	OY	QX	AP	JP	BU	mae	hzi	sog	ysi
649	16	V	II	III	08	16	13					HM	JO	DI	NR	BY	XZ	OS	PU	FQ	CT	tdp	dhb	fkb	uiv
649	15	II	IV	I	01	03	07					DS	HY	MR	GW	LX	AJ	BQ	CO	IP	NT	ldw	hzj	soh	wvg
649	14	IV	I	V	15	11	05	AI	BT	MV	HU	GM	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	V	imz	noa	tjv	xtk
649	13	I	III	II	13	20	03	FW	EL	DG	KN	LY	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	X	zgr	dgz	gjo	ryq
649	12	V	II	IV	18	10	07	RZ	OQ	CP	SX	MU	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	W	zdy	rkf	tjw	xtl
649	11	II	IV	III	02	26	15					KN	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	V	zea	rjy	soi	wvh
649	10	III	V	IV	23	21	01					LR	IK	MS	QU	HW	PT	GO	VX	FZ	EN	lrc	zbx	vbm	rxo
649	9	V	I	III	16	04	08					QY	BS	LN	KT	AP	IU	DW	HO	RV	JZ	edj	eyr	vby	tlh
649	8	IV	II	V	13	19	25					FI	NQ	SY	CU	BZ	AH	EL	TX	DO	KP	[illegible]	[illegible]	[illegible]	[illegible]
649	7	I	IV	II	09	03	22					UX	IZ	HN	BK	GQ	CP	FT	JY	MW	AR	[illegible]	[illegible]	[illegible]	[illegible]
649	6	III	I	V	11	18	14					DQ	GU	BW	NP	HK	AZ	CI	PO	JX	VY	[illegible]	[illegible]	[illegible]	[illegible]
649	5	V	II	IV	23	02	25	IL	AP	EU	HO	MV	CL	GK	OQ	BI	FU	HS	PX	NW	EY	[illegible]	[illegible]	[illegible]	[illegible]
649	4	II	IV	I	04	21	09	QT	WZ	KV	GM	AC	BL	OZ	EK	QW	OP	SU	DH	JM	TX	lsb	zby	vcy	ujb
649	3	V	I	II	19	11	06	BF	NR	DX	CS	KR	MP	CN	BF	EH	DZ	IW	AV	GJ	LO	lap	owd	iwu	wak
649	2	IV	V	I	16	14	02					BN	HU	EG	PY	KQ	CP	OS	JW	AI	VZ	aqd	bdy	iyf	xtd
649	1	II	I	III	23	12	10					DP	BM	NZ	CK	GV	HQ	AF	UY	SW	JO	kgl	cdf	giq	wuv

rotors

ring

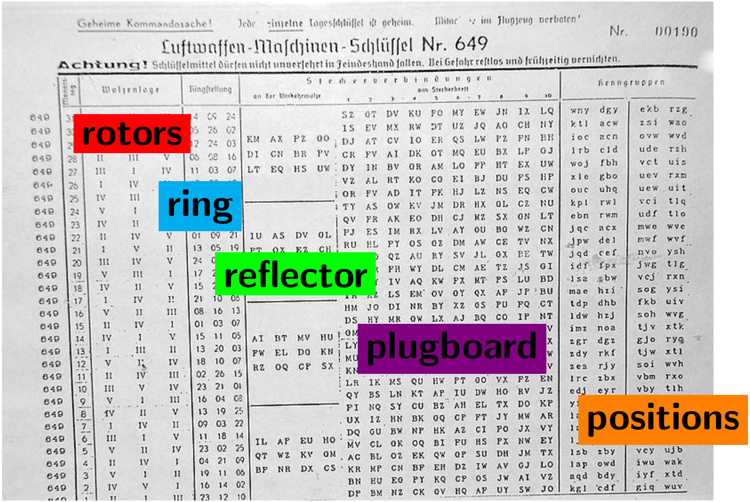
reflector

plugboard

positions

$5 \cdot 4 \cdot 3 \cdot 26^3 \cdot 24!/(12!2^{12}) \cdot 26!/(10!6!2^{10}) \cdot 26^3 \simeq$ 150 undecillion 789 decillion 931 nonillion 331 octillion

The enigma keyspace



rotors
ring
reflector
plugboard
positions

Geheime Kommandoſache! Jede einzelne Tagesſchlüſſel iſt geheim. Mitnahme im Flugzeug verboten!

Nr. 00190

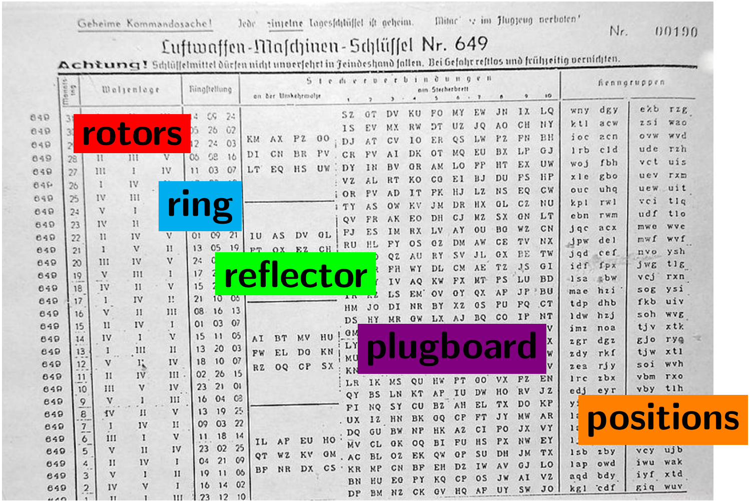
Luftwaffen-Maſchinen-Schlüſſel Nr. 649

Achtung! Schlüſſelmittel dürfen nicht unverſehrt in Feindeshand fallen. Bei Gefahr reſtlos und frühzeitig vernichten.

	Monatstag	Walzenlage			Ringſtellung			Steckerverbindungen														Kenngruppen			
								an der Umkehrwalze				am Steckerbrett													
												1	2	3	4	5	6	7	8	9	10				
649	31				14	09	24					SZ	OT	DV	KU	FO	MY	EW	JN	IX	LQ	wny	dgy	ezb	rzg
649	30				05	26	02					IS	EV	MX	RW	DT	UZ	JQ	AO	CH	NY	ktl	acw	zsi	wao
649	29				12	24	03	KM	AX	PZ	OO	DJ	AT	CV	IO	ER	QS	LW	PZ	FN	BH	ioc	acn	ovw	wvd
649	28	II	III	V	06	08	16	DI	CN	BR	PV	CR	PV	AI	DK	OT	MQ	EU	BX	LP	GJ	lrb	cld	ude	rzh
649	27	III	I	IV	11	03	07	LT	EQ	HS	UW	DY	IN	BV	OR	AM	LO	PP	HT	EX	UW	woj	fbh	vct	uis
649	26	I	IV									VZ	AL	RT	KO	CO	EI	BJ	DU	FS	HP	xle	gbo	uev	rxm
649	25	IV	III									OR	PV	AD	IT	PK	HJ	LZ	NS	EQ	CW	ouc	uhq	uew	uit
649	24	V	I									TY	AS	OW	KV	JM	DR	HX	GL	CZ	NU	kpl	rwl	vci	tlq
649	23	IV	II									QV	FR	AK	EO	DH	CJ	MZ	SX	GN	LT	ebn	rwm	udf	tlo
649	22	II	IV	V	01	09	21	IU	AS	DV	GL	FJ	ES	IM	RX	LV	AY	OU	BO	WZ	CN	jqc	acx	mwe	wve
649	21	I	V	II	13	05	19	PT	OX	EZ	CH	RU	HL	FY	OS	GZ	DM	AW	CE	TV	NX	jpw	del	mwf	wvf
649	20	III	IV	V	24	0							QZ	AU	RY	SV	JL	GX	BE	TW		jqd	cef	nvo	ysh
649	19	V	III	I	17	2							FH	WY	DL	CM	AE	TZ	JS	GI		idf	fpx	jwg	tlg
649	18	IV	II	V	15	2							IV	AQ	KW	FX	MT	PS	LU	BD		lsa	bw	vcj	rxn
649	17	I	IV	II	21	10	06					IR	KZ	LS	EN	OV	OY	QX	AP	JP	BU	mae	hzi	sog	ysi
649	16	V	II	III	08	16	13					HM	JO	DI	NR	BY	XZ	OS	PU	FQ	CT	tdp	dhb	fkb	uiv
649	15	II	IV	I	01	03	07					DS	HY	MR	GW	LX	AJ	BQ	CO	IP	NT	ldw	hzj	soh	wvg
649	14	IV	I	V	15	11	05	AI	BT	MV	HU	GM									V	imz	noa	tjv	xtk
649	13	I	III	II	13	20	03	FW	EL	DO	KN	LY									X	zgr	dgz	gjo	ryq
649	12	V	II	IV	18	10	07	RZ	OQ	CP	SX	MU									W	zdy	rkf	tjw	xtl
649	11	II	IV	III	02	26	15					KN									V	zea	rjy	soi	wvh
649	10	III	V	IV	23	21	01					LR	IK	MS	QU	HW	PT	GO	VX	FZ	EN	lrc	zbx	vbm	rxo
649	9	V	I	III	16	04	08					QY	BS	LN	KT	AP	IU	DW	HO	RV	JZ	edj	eyr	vby	tlh
649	8	IV	II	V	13	19	25					FI	NQ	SY	CU	BZ	AH	EL	TX	DO	KP	yi			
649	7	I	IV	II	09	03	22					UX	IZ	HN	BK	GQ	CP	FT	JY	MW	AR	la			
649	6	III	I	V	11	18	14	IL	AP	EU	HO	DQ	GU	BW	NP	HK	AZ	CI	PO	JX	VY	ls			
649	5	V	II	IV	23	02	25	QT	WZ	KV	GM	MV	CL	GK	OQ	BI	FU	HS	PX	NW	EY	lj			
649	4	II	IV	I	04	21	09	BF	NR	DX	CS	AC	BL	OZ	EK	QW	OP	SU	DH	JM	TX	lsb	zby	vcy	ujb
649	3	V	I	II	19	11	06					KR	MP	CN	BF	EH	DZ	IW	AV	GJ	LO	lap	owd	iwu	wak
649	2	IV	V	I	16	14	02					BN	HU	EG	PY	KQ	CP	OS	JW	AI	VZ	aqd	bdy	iyf	xtd
649	1	II	I	III	23	12	10					DP	BM	NZ	CK	GV	HQ	AP	UY	SW	JO	kgl	cdf	giq	wuv

$5 \cdot 4 \cdot 3 \cdot 26^3 \cdot 24!/(12!2^{12}) \cdot 26!/(10!6!2^{10}) \cdot 26^3 \simeq$ 150 undecillion 789 decillion 931 nonillion 331 octillion 314 septillion

The enigma keyspace



rotors
ring
reflector
plugboard
positions

Geheime Kommandosache! Jede einzelne Tagesſchlüſſel iſt geheim. Mitnahme im Flugzeug verboten! Nr. 00190

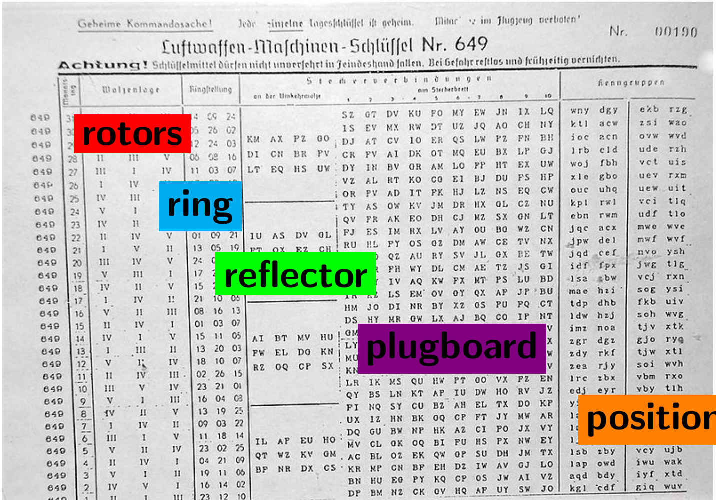
Luftwaffen-Maſchinen-Schlüſſel Nr. 649

Achtung! Schlüſſelmittel dürfen nicht unverſehrt in Feindeshand fallen. Bei Gefahr reſtlos und frühzeitig vernichten.

	Monatstag	Walzenlage			Ringſtellung			Steckerverbindungen														Kenngruppen			
								an der Umkehrwalze				am Steckerbrett													
												1	2	3	4	5	6	7	8	9	10				
649	31	[illegible]	[illegible]	[illegible]	[illegible]	09	24					SZ	OT	DV	KU	FO	MY	EW	JN	IX	LQ	wny	dgy	ezb	rzg
649	30	[illegible]	[illegible]	[illegible]	05	26	02					IS	EV	MX	RW	DT	UZ	JQ	AO	CH	NY	ktl	acw	zsi	wao
649	29	[illegible]	[illegible]	[illegible]	12	24	03	KM	AX	PZ	GO	DJ	AT	CV	IO	ER	QS	LW	PZ	FN	BH	ioc	acn	ovw	wvd
649	28	II	III	V	06	08	16	DI	CN	BR	PV	CR	FV	AI	DK	OT	MQ	EU	BX	LP	GJ	lrb	cld	ude	rzh
649	27	III	I	IV	11	03	07	LT	EQ	HS	UW	DY	IN	BV	GR	AM	LO	PF	HT	EX	UW	woj	fbh	vct	uis
649	26	I	IV	[illegible]	[illegible]	[illegible]	[illegible]					VZ	AL	RT	KO	CG	EI	BJ	DU	FS	HP	xle	gbo	uev	rxm
649	25	IV	III	[illegible]	[illegible]	[illegible]	[illegible]					OR	PV	AD	IT	PK	HJ	LZ	NS	EQ	CW	ouc	uhq	uew	uit
649	24	V	I	[illegible]	[illegible]	[illegible]	[illegible]					TY	AS	OW	KV	JM	DR	HX	GL	CZ	NU	kpl	rwl	vci	tlq
649	23	IV	II	[illegible]	[illegible]	[illegible]	[illegible]					QV	FR	AK	EO	DH	CJ	MZ	SX	GN	LT	ebn	rwm	udf	tlo
649	22	II	IV	V	01	09	21	IU	AS	DV	GL	FJ	ES	IM	RX	LV	AY	OU	BG	WZ	CN	jqc	acx	mwe	wve
649	21	I	V	II	13	05	19	PT	OX	EZ	CH	RU	HL	FY	OS	GZ	DM	AW	CE	TV	NX	jpw	del	mwf	wvf
649	20	III	IV	V	24	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	QZ	AU	RY	SV	JL	GX	BE	TW	jqd	cef	nvo	ysh
649	19	V	III	I	17	[illegible]	[illegible]					[illegible]	[illegible]	FH	WY	DL	CM	AE	TZ	JS	GI	idf	fpx	jwg	tlg
649	18	IV	II	V	15	[illegible]	[illegible]					[illegible]	[illegible]	IV	AQ	KW	FX	MT	PS	LU	BD	lsa	[illegible]	vcj	rxn
649	17	I	IV	II	21	10	06					IR	[illegible]	LS	EM	OV	OY	QX	AP	JP	BU	mae	hzi	sog	ysi
649	16	V	II	III	08	16	13					HM	JO	DI	NR	BY	XZ	OS	PU	PQ	CT	tdp	dhb	fkb	uiv
649	15	II	IV	I	01	03	07					DS	HY	MR	GW	LX	AJ	BQ	CO	IP	NT	ldw	hzj	soh	wvg
649	14	IV	I	V	15	11	05	AI	BT	MV	HU	GM	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	V	imz	noa	tjv	xtk
649	13	I	III	II	13	20	03	FW	EL	DQ	KN	LY	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	X	zgr	dgz	gjo	ryq
649	12	V	II	IV	18	10	07	RZ	OQ	CP	SX	MU	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	W	zdy	rkf	tjw	xtl
649	11	II	IV	III	02	26	15					KN	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	V	zea	rjy	soi	wvh
649	10	III	V	IV	23	21	01					LR	IK	MS	QU	HW	PT	GO	VX	FZ	EN	lrc	zbx	vbm	rxo
649	9	V	I	III	16	04	08					QY	BS	LN	KT	AP	IU	DW	HO	RV	JZ	edj	eyr	vby	tlh
649	8	IV	II	V	13	19	25					FI	NQ	SY	CU	BZ	AH	EL	TX	DO	KP	[illegible]	[illegible]	[illegible]	[illegible]
649	7	I	IV	II	09	03	22					UX	IZ	HN	BK	GQ	CP	FT	JY	MW	AR	[illegible]	[illegible]	[illegible]	[illegible]
649	6	III	I	V	11	18	14	IL	AP	EU	HO	DQ	GU	BW	NP	HK	AZ	CI	PO	JX	VY	[illegible]	[illegible]	[illegible]	[illegible]
649	5	V	II	IV	23	02	25	QT	WZ	KV	GM	MV	CL	GK	OQ	BI	FU	HS	PX	NW	EY	[illegible]	[illegible]	[illegible]	[illegible]
649	4	II	IV	I	04	21	09	BF	NR	DX	CS	AC	BL	OZ	EK	QW	OP	SU	DH	JM	TX	lsb	zby	vcy	ujb
649	3	V	I	II	19	11	06					KR	MP	CN	BF	EH	DZ	IW	AV	GJ	LO	lap	owd	iwu	wak
649	2	IV	V	I	16	14	02					BN	HU	EG	PY	KQ	CP	OS	JW	AI	VZ	aqd	bdy	iyf	xtd
649	1	II	I	III	23	12	10					DP	BM	NZ	CK	GV	HQ	AF	UY	SW	JO	kgl	cdf	giq	wuv

$5 \cdot 4 \cdot 3 \cdot 26^3 \cdot 24!/(12!2^{12}) \cdot 26!/(10!6!2^{10}) \cdot 26^3 \simeq$ 150 undecillion 789 decillion 931 nonillion 331 octillion 314 septillion 839 sextillion

The enigma keyspace


rotors
ring
reflector
plugboard
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Geheime Kommandosache! Jede einzelne Tagesſchlüſſel iſt geheim. Mitnahme im Flugzeug verboten! Nr. 00190

Luftwaffen-Maſchinen-Schlüſſel Nr. 649

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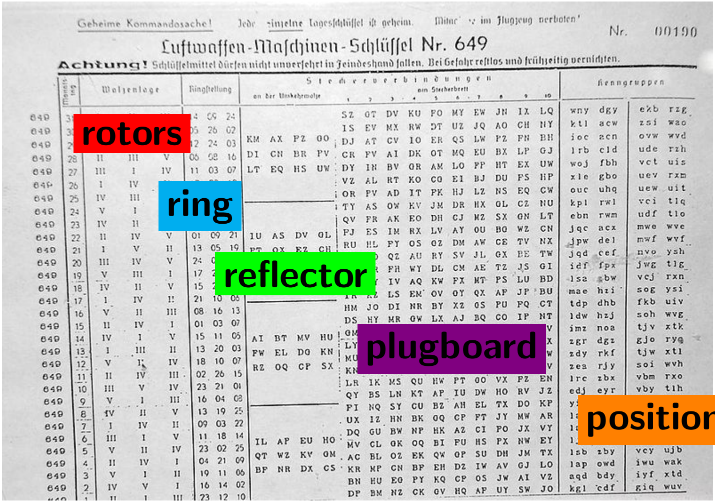
	Monatstag	Walzenlage			Ringſtellung			Steckerverbindungen														Kenngruppen			
								an der Umkehrwalze				am Steckerbrett													
												1	2	3	4	5	6	7	8	9	10				
649	31	[illegible]	[illegible]	[illegible]	[illegible]	09	24					SZ	OT	DV	KU	FO	MY	EW	JN	IX	LQ	wny	dgy	ezb	rzg
649	30	[illegible]	[illegible]	[illegible]	[illegible]	26	02					IS	EV	MX	RW	DT	UZ	JQ	AO	CH	NY	ktl	acw	zsi	wao
649	29	[illegible]	[illegible]	[illegible]	12	24	03	KM	AX	PZ	OO	DJ	AT	CV	IO	ER	QS	LW	PZ	FN	BH	ioc	acn	ovw	wvd
649	28	II	III	V	06	08	16	DI	CN	BR	PV	CR	FV	AI	DK	OT	MQ	EU	BX	LP	GJ	lrb	cld	ude	rzh
649	27	III	I	IV	11	03	07	LT	EQ	HS	UW	DY	IN	BV	OR	AM	LO	PP	HT	EX	UW	woj	fbh	vct	uis
649	26	I	IV	[illegible]	[illegible]	[illegible]	[illegible]					VZ	AL	RT	KO	CO	EI	BJ	DU	FS	HP	xle	gbo	uev	rxm
649	25	IV	III	[illegible]	[illegible]	[illegible]	[illegible]					OR	PV	AD	IT	PK	HJ	LZ	NS	EQ	CW	ouc	uhq	uew	uit
649	24	V	I	[illegible]	[illegible]	[illegible]	[illegible]					TY	AS	OW	KV	JM	DR	HX	GL	CZ	NU	kpl	rwl	vci	tlq
649	23	IV	II	[illegible]	[illegible]	[illegible]	[illegible]					QV	FR	AK	EO	DH	CJ	MZ	SX	GN	LT	ebn	rwm	udf	tlo
649	22	II	IV	V	01	09	21	IU	AS	DV	GL	FJ	ES	IM	RX	LV	AY	OU	BG	WZ	CN	jqc	acx	mwe	wve
649	21	I	V	II	13	05	19	PT	OX	EZ	CH	RU	HL	FY	OS	GZ	DM	AW	CE	TV	NX	jpw	del	mwf	wvf
649	20	III	IV	V	24	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	QZ	AU	RY	SV	JL	GX	BE	TW	jqd	cef	nvo	ysh
649	19	V	III	I	17	[illegible]	[illegible]					[illegible]	[illegible]	FH	WY	DL	CM	AE	TZ	JS	GI	idf	fpx	jwg	tlg
649	18	IV	II	V	15	[illegible]	[illegible]					[illegible]	[illegible]	IV	AQ	KW	FX	MT	PS	LU	BD	lsa	[illegible]	vcj	rxn
649	17	I	IV	II	21	10	06					[illegible]	[illegible]	LS	EN	OV	OY	QX	AF	JP	BU	mae	hzi	sog	ysi
649	16	V	II	III	08	16	13					HM	JO	DI	NR	BY	XZ	OS	PU	FQ	CT	tdp	dhb	fkb	uiv
649	15	II	IV	I	01	03	07					DS	HY	MR	OW	LX	AJ	BQ	CO	IP	NT	ldw	hzj	soh	wvg
649	14	IV	I	V	15	11	05	AI	BT	MV	HU	GM	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	V	imz	noa	tjv	xtk
649	13	I	III	II	13	20	03	FW	EL	DO	KN	LY	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	X	zgr	dgz	gjo	ryq
649	12	V	II	IV	18	10	07	RZ	OQ	CP	SX	MU	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	W	zdy	rkf	tjw	xtl
649	11	II	IV	III	02	26	15					KN	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	V	zea	rjy	soi	wvh
649	10	III	V	IV	23	21	01					LR	IK	MS	QU	HW	PT	GO	VX	FZ	EN	lrc	zbx	vbm	rxo
649	9	V	I	III	16	04	08					QY	BS	LN	KT	AP	IU	DW	HO	RV	JZ	edj	eyr	vby	tlh
649	8	IV	II	V	13	19	25					FI	NQ	SY	CU	BZ	AH	EL	TX	DO	KP	[illegible]	[illegible]	[illegible]	[illegible]
649	7	I	IV	II	09	03	22					UX	IZ	HN	BK	OQ	CP	FT	JY	MW	AR	[illegible]	[illegible]	[illegible]	[illegible]
649	6	III	I	V	11	18	14					DQ	GU	BW	NP	HK	AZ	CI	PO	JX	VY	[illegible]	[illegible]	[illegible]	[illegible]
649	5	V	II	IV	23	02	25	IL	AP	EU	HO	MV	CL	GK	OQ	BI	FU	HS	PX	NW	EY	[illegible]	[illegible]	[illegible]	[illegible]
649	4	II	IV	I	04	21	09	QT	WZ	KV	GM	AC	BL	OZ	EK	QW	OP	SU	DH	JM	TX	lsb	zby	vcy	ujb
649	3	V	I	II	19	11	06	BF	NR	DX	CS	KR	MP	CN	BF	EH	DZ	IW	AV	GJ	LO	lap	owd	iwu	wak
649	2	IV	V	I	16	14	02					BN	HU	EG	PY	KQ	CP	OS	JW	AI	VZ	aqd	bdy	iyf	xtd
[illegible]	1	II	I	III	23	12	10					DP	BM	NZ	CK	GV	HQ	AF	UY	SW	JO	kgl	cdf	giq	wuv

$5 \cdot 4 \cdot 3 \cdot 26^3 \cdot 24!/(12!2^{12}) \cdot 26!/(10!6!2^{10}) \cdot 26^3 \simeq$ 150 undecillion 789 decillion 931 nonillion 331 octillion 314 septillion 839 sextillion 42 quintillion

The enigma keyspace


rotors
ring
reflector
plugboard
positions

Geheime Kommandosache!   Jede einzelne Tagesſchlüſſel iſt geheim.   Mitnahme im Flugzeug verboten!   Nr. 00190

Luftwaffen-Maſchinen-Schlüſſel Nr. 649

Achtung! Schlüſſelmittel dürfen nicht unverſehrt in Feindeshand fallen. Bei Gefahr reſtlos und frühzeitig vernichten.

	Monatstag	Walzenlage			Ringſtellung			Steckerverbindungen														Kenngruppen			
								an der Umkehrwalze				am Steckerbrett													
												1	2	3	4	5	6	7	8	9	10				
649	31	[illegible]	[illegible]	[illegible]	[illegible]	09	24					SZ	OT	DV	KU	FO	MY	EW	JN	IX	LQ	wny	dgy	ezb	rzg
649	30	[illegible]	[illegible]	[illegible]	05	26	02					IS	EV	MX	RW	DT	UZ	JQ	AO	CH	NY	ktl	acw	zsi	wao
649	29	[illegible]	[illegible]	[illegible]	12	24	03	KM	AX	PZ	OO	DJ	AT	CV	IO	ER	QS	LW	PZ	FN	BH	ioc	acn	ovw	wvd
649	28	II	III	V	06	08	16	DI	CN	BR	PV	CR	PV	AI	DK	OT	MQ	EU	BX	LP	GJ	lrb	cld	ude	rzh
649	27	III	I	IV	11	03	07	LT	EQ	HS	UW	DY	IN	BV	OR	AM	LO	PP	HT	EX	UW	woj	fbh	vct	uis
649	26	I	IV	[illegible]	[illegible]	[illegible]	[illegible]					VZ	AL	RT	KO	CG	EI	BJ	DU	FS	HP	xle	gbo	uev	rxm
649	25	IV	III	[illegible]	[illegible]	[illegible]	[illegible]					OR	PV	AD	IT	PK	HJ	LZ	NS	EQ	CW	ouc	uhq	uew	uit
649	24	V	I	[illegible]	[illegible]	[illegible]	[illegible]					TY	AS	OW	KV	JM	DR	HX	GL	CZ	NU	kpl	rwl	vci	tlq
649	23	IV	II	[illegible]	[illegible]	[illegible]	[illegible]					QV	FR	AK	EO	DH	CJ	MZ	SX	GN	LT	ebn	rwm	udf	tlo
649	22	II	IV	V	01	09	21	IU	AS	DV	GL	PJ	ES	IM	RX	LV	AY	OU	BO	WZ	CN	jqc	acx	mwe	wve
649	21	I	V	II	13	05	19	PT	OX	EZ	CH	RU	HL	PY	OS	GZ	DM	AW	CE	TV	NX	jpw	del	mwf	wvf
649	20	III	IV	V	24	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	QZ	AU	RY	SV	JL	GX	BE	TW	jqd	cef	nvo	ysh
649	19	V	III	I	17	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	FH	WY	DL	CM	AE	TZ	JS	GI	idf	fpx	jwg	tlg
649	18	IV	II	V	15	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	IV	AQ	KW	FX	MT	PS	LU	BD	lsa	[illegible]	vcj	rxn
649	17	I	IV	II	21	10	06					[illegible]	[illegible]	LS	EM	OV	OY	QX	AF	JP	BU	mae	hzi	sog	ysi
649	16	V	II	III	08	16	13					HM	JO	DI	NR	BY	XZ	OS	PU	FQ	CT	tdp	dhb	fkb	uiv
649	15	II	IV	I	01	03	07					DS	HY	MR	GW	LX	AJ	BQ	CO	IP	NT	ldw	hzj	soh	wvg
649	14	IV	I	V	15	11	05	AI	BT	MV	HU	GM	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	V	imz	noa	tjv	xtk
649	13	I	III	II	13	20	03	FW	EL	DO	KN	LY	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	X	zgr	dgz	gjo	ryq
649	12	V	II	IV	18	10	07	RZ	OQ	CP	SX	MU	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	W	zdy	rkf	tjw	xtl
649	11	II	IV	III	02	26	15					KN	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	V	zea	rjy	soi	wvh
649	10	III	V	IV	23	21	01					LR	IK	MS	QU	HW	PT	GO	VX	FZ	EN	lrc	zbx	vbm	rxo
649	9	V	I	III	16	04	08					QY	BS	LN	KT	AP	IU	DW	HO	RV	JZ	edj	eyr	vby	tlh
649	8	IV	II	V	13	19	25					FI	NQ	SY	CU	BZ	AH	EL	TX	DO	KP	[illegible]	[illegible]	[illegible]	[illegible]
649	7	I	IV	II	09	03	22					UX	IZ	HN	BK	GQ	CP	FT	JY	MW	AR	[illegible]	[illegible]	[illegible]	[illegible]
649	6	III	I	V	11	18	14					DQ	GU	BW	NP	HK	AZ	CI	PO	JX	VY	[illegible]	[illegible]	[illegible]	[illegible]
649	5	V	II	IV	23	02	25	IL	AP	EU	HO	MV	CL	GK	OQ	BI	FU	HS	PX	NW	EY	[illegible]	[illegible]	[illegible]	[illegible]
649	4	II	IV	I	04	21	09	QT	WZ	KV	GM	AC	BL	OZ	EK	QW	OP	SU	DH	JM	TX	lsb	zby	vcy	ujb
649	3	V	I	II	19	11	06	BF	NR	DX	CS	KR	MP	CN	BF	EH	DZ	IW	AV	GJ	LO	lap	owd	iwu	wak
649	2	IV	V	I	16	14	02					BN	HU	EG	PY	KQ	CP	OS	JW	AI	VZ	aqd	bdy	iyf	xtd
649	1	II	I	III	23	12	10					DP	BM	NZ	CK	GV	HQ	AF	UY	SW	JO	kgl	cdf	giq	wuv

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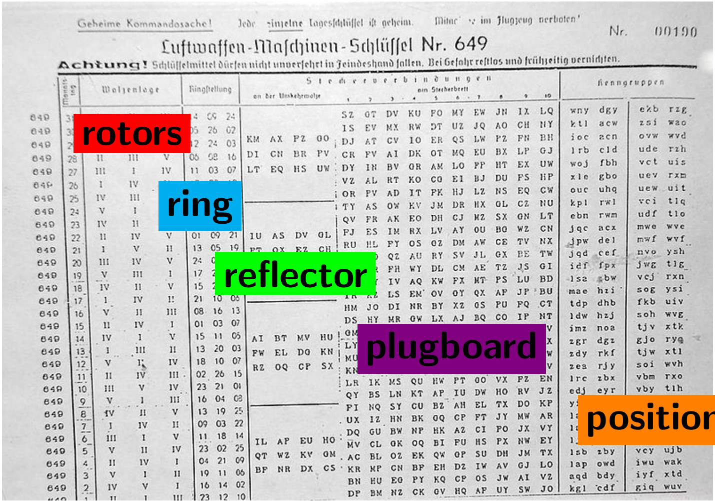
The enigma keyspace



Geheime Kommandosache! Jede einzelne Tagesſchlüſſel iſt geheim. Mitnahme im Flugzeug verboten! Nr. 00190

Luftwaffen-Maſchinen-Schlüſſel Nr. 649

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	Monatstag	Walzenlage			Ringſtellung			Steckerverbindungen														Kenngruppen			
								an der Umkehrwalze				am Steckerbrett													
												1	2	3	4	5	6	7	8	9	10				
649	31	[illegible]	[illegible]	[illegible]	[illegible]	09	24					SZ	OT	DV	KU	FO	MY	EW	JN	IX	LQ	wny	dgy	ezb	rzg
649	30	[illegible]	[illegible]	[illegible]	05	26	02					IS	EV	MX	RW	DT	UZ	JQ	AO	CH	NY	ktl	acw	zsi	wao
649	29	[illegible]	[illegible]	[illegible]	12	24	03	KM	AX	PZ	OO	DJ	AT	CV	IO	ER	QS	LW	PZ	FN	BH	ioc	zcn	ovw	wvd
649	28	II	III	V	06	08	16	DI	CN	BR	PV	CR	FV	AI	DK	OT	MQ	EU	BX	LP	GJ	lrb	cld	ude	rzh
649	27	III	I	IV	11	03	07	LT	EQ	HS	UW	DY	IN	BV	OR	AM	LO	PP	HT	EX	UW	woj	fbh	vct	uis
649	26	I	IV	[illegible]	[illegible]	[illegible]	[illegible]					VZ	AL	RT	KO	CO	EI	BJ	DU	FS	HP	xle	gbo	uev	rxm
649	25	IV	III	[illegible]	[illegible]	[illegible]	[illegible]					OR	PV	AD	IT	PK	HJ	LZ	NS	EQ	CW	ouc	uhq	uew	uit
649	24	V	I	[illegible]	[illegible]	[illegible]	[illegible]					TY	AS	OW	KV	JM	DR	HX	GL	CZ	NU	kpl	rwl	vci	tlq
649	23	IV	II	[illegible]	[illegible]	[illegible]	[illegible]					QV	FR	AK	EO	DH	CJ	MZ	SX	GN	LT	ebn	rwm	udf	tlo
649	22	II	IV	V	01	09	21	IU	AS	DV	GL	FJ	ES	IM	RX	LV	AY	OU	BG	WZ	CN	jqc	acx	mwe	wve
649	21	I	V	II	13	05	19	PT	OX	EZ	CH	RU	HL	FY	OS	GZ	DM	AW	CE	TV	NX	jpw	del	mwf	wvf
649	20	III	IV	V	24	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	QZ	AU	RY	SV	JL	GX	BE	TW	jqd	cef	nvo	ysh
649	19	V	III	I	17	[illegible]	[illegible]					[illegible]	[illegible]	FH	WY	DL	CM	AE	TZ	JS	GI	idf	fpx	jwg	tlg
649	18	IV	II	V	15	[illegible]	[illegible]					[illegible]	[illegible]	IV	AQ	KW	FX	MT	PS	LU	BD	lsa	gbw	vcj	rxn
649	17	I	IV	II	21	10	06					[illegible]	[illegible]	LS	EN	OV	OY	QX	AP	JP	BU	mae	hzi	sog	ysi
649	16	V	II	III	08	16	13					HM	JO	DI	NR	BY	XZ	OS	PU	FQ	CT	tdp	dhb	fkb	uiv
649	15	II	IV	I	01	03	07					DS	HY	MR	GW	LX	AJ	BQ	CO	IP	NT	ldw	hzj	soh	wvg
649	14	IV	I	V	15	11	05	AI	BT	MV	HU	GM	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	imz	noa	tjv	xtk
649	13	I	III	II	13	20	03	FW	EL	DO	KN	LY	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	zgr	dgz	gjo	ryq
649	12	V	II	IV	18	10	07	RZ	OQ	CP	SX	MU	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	zdy	rkf	tjw	xtl
649	11	II	IV	III	02	26	15					KN	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	zea	rjy	soi	wvh
649	10	III	V	IV	23	21	01					LR	IK	MS	QU	HW	PT	GO	VX	FZ	EN	lrc	zbx	vbm	rxo
649	9	V	I	III	16	04	08					QY	BS	LN	KT	AP	IU	DW	HO	RV	JZ	edj	eyr	vby	tlh
649	8	IV	II	V	13	19	25					FI	NQ	SY	CU	BZ	AH	EL	TX	DO	KP	[illegible]	[illegible]	[illegible]	[illegible]
649	7	I	IV	II	09	03	22					UX	IZ	HN	BK	GQ	CP	FT	JY	MW	AR	[illegible]	[illegible]	[illegible]	[illegible]
649	6	III	I	V	11	18	14					DQ	GU	BW	NP	HK	AZ	CI	PO	JX	VY	[illegible]	[illegible]	[illegible]	[illegible]
649	5	V	II	IV	23	02	25	IL	AP	EU	HO	MV	CL	GK	OQ	BI	FU	HS	PX	NW	EY	[illegible]	[illegible]	[illegible]	[illegible]
649	4	II	IV	I	04	21	09	QT	WZ	KV	GM	AC	BL	OZ	EK	QW	OP	SU	DH	JM	TX	lsb	zby	vcy	ujb
649	3	V	I	II	19	11	06	BF	NR	DX	CS	KR	MP	CN	BF	EH	DZ	IW	AV	GJ	LO	lap	owd	iwu	wak
649	2	IV	V	I	16	14	02					BN	HU	EG	PY	KQ	CP	OS	JW	AI	VZ	aqd	bdy	iyf	xtd
649	1	II	I	III	23	12	10					DP	BM	NZ	CK	GV	HQ	AP	UY	SW	JO	kgl	cdf	giq	wuv

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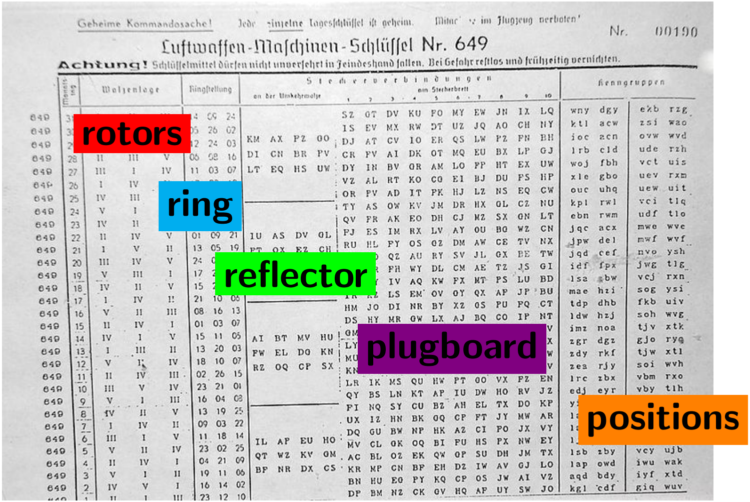
The enigma keyspace


rotors
ring
reflector
plugboard
positions

Geheime Kommandosache! Jede einzelne Tagesſchlüſſel iſt geheim. Mitna[illegible] im Flugzeug verboten! Nr. 00190

Luftwaffen-Maſchinen-Schlüſſel Nr. 649

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	Monatstag	Walzenlage			Ringſtellung			Steckerverbindungen														Kenngruppen			
								an der Umkehrwalze				am Steckerbrett 1	2	3	4	5	6	7	8	9	10				
649	31	[illegible]	[illegible]	[illegible]	[illegible]	09	24					SZ	OT	DV	KU	FO	MY	EW	JN	IX	LQ	wny	dgy	ezb	rzg
649	30	[illegible]	[illegible]	[illegible]	05	26	02					IS	EV	MX	RW	DT	UZ	JQ	AO	CH	NY	ktl	acw	zsi	wao
649	29	[illegible]	[illegible]	[illegible]	12	24	03	KM	AX	PZ	OO	DJ	AT	CV	IO	ER	QS	LW	PZ	FN	BH	ioc	acn	ovw	wvd
649	28	II	III	V	06	08	16	DI	CN	BR	PV	CR	FV	AI	DK	OT	MQ	EU	BX	LP	GJ	lrb	cld	ude	rzh
649	27	III	I	IV	11	03	07	LT	EQ	HS	UW	DY	IN	BV	OR	AM	LO	PP	HT	EX	UW	woj	fbh	vct	uis
649	26	I	IV	[illegible]	[illegible]	[illegible]	[illegible]					VZ	AL	RT	KO	CG	EI	BJ	DU	FS	HP	xle	gbo	uev	rxm
649	25	IV	III	[illegible]	[illegible]	[illegible]	[illegible]					OR	PV	AD	IT	PK	HJ	LZ	NS	EQ	CW	ouc	uhq	uew	uit
649	24	V	I	[illegible]	[illegible]	[illegible]	[illegible]					TY	AS	OW	KV	JM	DR	HX	GL	CZ	NU	kpl	rwl	vci	tlq
649	23	IV	II	[illegible]	[illegible]	[illegible]	[illegible]					QV	FR	AK	EO	DH	CJ	MZ	SX	GN	LT	ebn	rwm	udf	tlo
649	22	II	IV	V	01	09	21	IU	AS	DV	GL	FJ	ES	IM	RX	LV	AY	OU	BG	WZ	CN	jqc	acx	mwe	wve
649	21	I	V	II	13	05	19	ET	OX	EZ	CH	RU	HL	PY	OS	GZ	DM	AW	CE	TV	NX	jpw	del	mwf	wvf
649	20	III	IV	V	24	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	QZ	AU	RY	SV	JL	GX	BE	TW	jqd	cef	nvo	ysh
649	19	V	III	I	17	[illegible]	[illegible]					[illegible]	[illegible]	FH	WY	DL	CM	AE	TZ	JS	GI	idf	fpx	jwg	tlg
649	18	IV	II	V	15	[illegible]	[illegible]					[illegible]	[illegible]	IV	AQ	KW	FX	MT	PS	LU	BD	lsa	[illegible]	vcj	rxn
649	17	I	IV	II	21	10	06					[illegible]	[illegible]	LS	EM	OV	OY	QX	AP	JP	BU	mae	hzi	sog	ysi
649	16	V	II	III	08	16	13					HM	JO	DI	NR	BY	XZ	OS	PU	PQ	CT	tdp	dhb	fkb	uiv
649	15	II	IV	I	01	03	07					DS	HY	MR	GW	LX	AJ	BQ	CO	IP	NT	ldw	hzj	soh	wvg
649	14	IV	I	V	15	11	05	AI	BT	MV	HU	GM	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	imz	noa	tjv	xtk
649	13	I	III	II	13	20	03	FW	EL	DO	KN	LY	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	zgr	dgz	gjo	ryq
649	12	V	II	IV	18	10	07	RZ	OQ	CP	SX	MU	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	zdy	rkf	tjw	xtl
649	11	II	IV	III	02	26	15					KN	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	zea	rjy	soi	wvh
649	10	III	V	IV	23	21	01					LR	IK	MS	QU	HW	PT	GO	VX	FZ	EN	lrc	zbx	vbm	rxo
649	9	V	I	III	16	04	08					QY	BS	LN	KT	AP	IU	DW	HO	RV	JZ	edj	eyr	vby	tlh
649	8	IV	II	V	13	19	25					FI	NQ	SY	CU	BZ	AH	EL	TX	DO	KP	[illegible]	[illegible]	[illegible]	[illegible]
649	7	I	IV	II	09	03	22					UX	IZ	HN	BK	GQ	CP	FT	JY	MW	AR	[illegible]	[illegible]	[illegible]	[illegible]
649	6	III	I	V	11	18	14	IL	AP	EU	HO	DQ	GU	BW	NP	HK	AZ	CI	PO	JX	VY	[illegible]	[illegible]	[illegible]	[illegible]
649	5	V	II	IV	23	02	25	QT	WZ	KV	GM	MV	CL	GK	OQ	BI	FU	HS	PX	NW	EY	[illegible]	[illegible]	[illegible]	[illegible]
649	4	II	IV	I	04	21	09	BF	NR	DX	CS	AC	BL	OZ	EK	QW	OP	SU	DH	JM	TX	lsb	zby	vcy	ujb
649	3	V	I	II	19	11	06					KR	MP	CN	BF	EH	DZ	IW	AV	GJ	LO	lap	owd	iwu	wak
649	2	IV	V	I	16	14	02					BN	HU	EG	PY	KQ	CP	OS	JW	AI	VZ	aqd	bdy	iyf	xtd
649	1	II	I	III	23	12	10					DP	BM	NZ	CK	GV	HQ	AP	UY	SW	JO	kgl	cdf	giq	wuv

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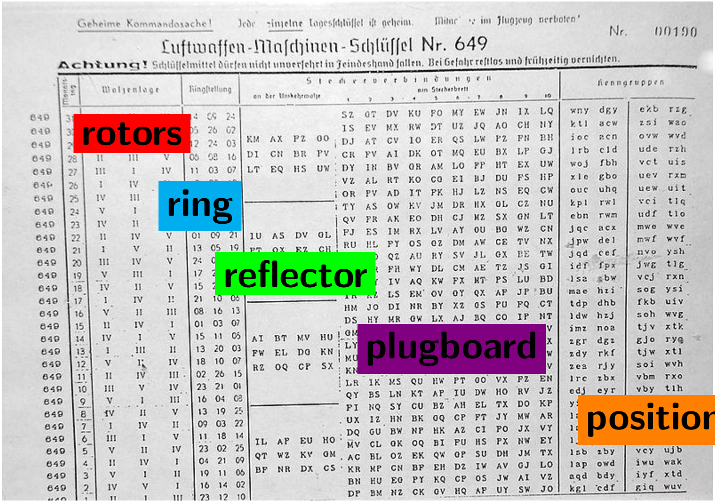
rotors
ring
reflector
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positions

Geheime Kommandoſache!   Jede einzelne Tagesſchlüſſel iſt geheim.   Mitnahme im Flugzeug verboten!   Nr. 00190

Luftwaffen-Maſchinen-Schlüſſel Nr. 649

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	Monatstag	Walzenlage			Ringſtellung			Steckerverbindungen an der Umkehrwalze				am Steckerbrett 1	2	3	4	5	6	7	8	9	10	Kenngruppen			
649	31	[illegible]	[illegible]	[illegible]	[illegible]	09	24					SZ	OT	DV	KU	FO	MY	EW	JN	IX	LQ	wny	dgy	ezb	rzg
649	30	[illegible]	[illegible]	[illegible]	05	26	02					IS	EV	MX	RW	DT	UZ	JQ	AO	CH	NY	ktl	acw	zsi	wao
649	29	[illegible]	[illegible]	[illegible]	12	24	03	KM	AX	PZ	OO	DJ	AT	CV	IO	ER	QS	LW	PZ	FN	BH	ioc	acn	ovw	wvd
649	28	II	III	V	06	08	16	DI	CN	BR	PV	CR	PV	AI	DK	OT	MQ	EU	BX	LP	GJ	lrb	cld	ude	rzh
649	27	III	I	IV	11	03	07	LT	EQ	HS	UW	DY	IN	BV	QR	AM	LO	FP	HT	EX	UW	woj	fbh	vct	uis
649	26	I	IV	[illegible]	[illegible]	[illegible]	[illegible]					VZ	AL	RT	KO	CG	EI	BJ	DU	FS	HP	xle	gbo	uev	rxm
649	25	IV	III	[illegible]	[illegible]	[illegible]	[illegible]					OR	PV	AD	IT	PK	HJ	LZ	NS	EQ	CW	ouc	uhq	uew	uit
649	24	V	I	[illegible]	[illegible]	[illegible]	[illegible]					TY	AS	OW	KV	JM	DR	HX	GL	CZ	NU	kpl	rwl	vci	tlq
649	23	IV	II	[illegible]	[illegible]	[illegible]	[illegible]					QV	FR	AK	EO	DH	CJ	MZ	SX	GN	LT	ebn	rwm	udf	tlo
649	22	II	IV	V	01	09	21	IU	AS	DV	GL	PJ	ES	IM	RX	LV	AY	OU	BG	WZ	CN	jqc	acx	mwe	wve
649	21	I	V	II	13	05	19	PT	OX	EZ	CH	RU	HL	FY	OS	GZ	DM	AW	CE	TV	NX	jpw	del	mwf	wvf
649	20	III	IV	V	24	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	QZ	AU	RY	SV	JL	GX	BE	TW	jqd	cef	nvo	ysh
649	19	V	III	I	17	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	FH	WY	DL	CM	AE	TZ	JS	GI	idf	fpx	jwg	tlg
649	18	IV	II	V	15	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	IV	AQ	KW	FX	MT	PS	LU	BD	lsa	[illegible]	vcj	rxn
649	17	I	IV	II	21	10	06					[illegible]	[illegible]	LS	EN	OV	OY	QX	AP	JP	BU	mae	hzi	sog	ysi
649	16	V	II	III	08	16	13					HM	JO	DI	NR	BY	XZ	OS	PU	FQ	CT	tdp	dhb	fkb	uiv
649	15	II	IV	I	01	03	07					DS	HY	MR	GW	LX	AJ	BQ	CO	IP	NT	ldw	hzj	soh	wvg
649	14	IV	I	V	15	11	05	AI	BT	MV	HU	GM	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	imz	noa	tjv	xtk
649	13	I	III	II	13	20	03	FW	EL	DO	KN	LY	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	zgr	dgz	gjo	ryq
649	12	V	II	IV	18	10	07	RZ	OQ	CP	SX	MU	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	zdy	rkf	tjw	xtl
649	11	II	IV	III	02	26	15					KN	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	zea	rjy	soi	wvh
649	10	III	V	IV	23	21	01					LR	IK	MS	QU	HW	PT	GO	VX	FZ	EN	lrc	zbx	vbm	rxo
649	9	V	I	III	16	04	08					QY	BS	LN	KT	AP	IU	DW	HO	RV	JZ	edj	eyr	vby	tlh
649	8	IV	II	V	13	19	25					FI	NQ	SY	CU	BZ	AH	EL	TX	DO	KP	[illegible]	[illegible]	[illegible]	[illegible]
649	7	I	IV	II	09	03	22					UX	IZ	HN	BK	GQ	CP	FT	JY	MW	AR	[illegible]	[illegible]	[illegible]	[illegible]
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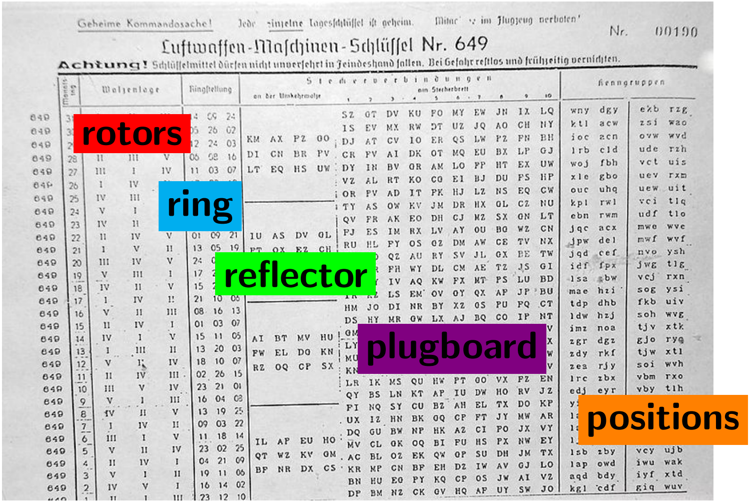

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649	[illegible]	[illegible]	[illegible]	[illegible]	12	24	03	KM	AX	PZ	OO	DJ	AT	CV	IO	ER	QS	LW	PZ	FN	BH	ioc	acn	ovw	wvd
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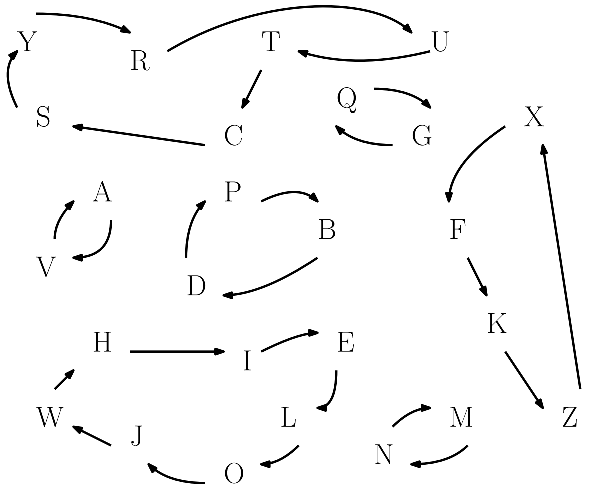
$\simeq 10^{38}$ keys

Cryptanalysis of enigma

A random permutation of the alphabet:



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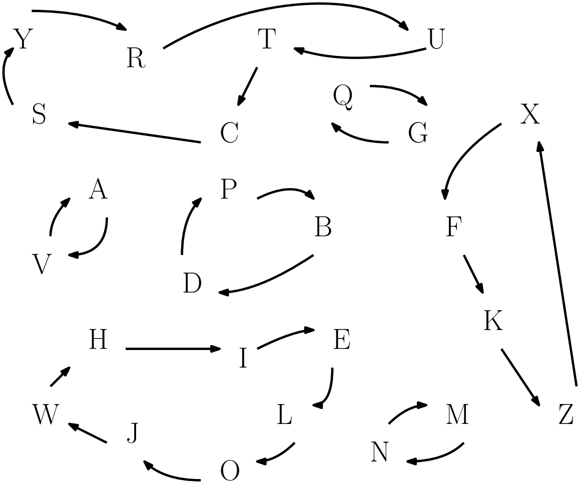

Cycle structure: 6-2-2-3-4-7-2

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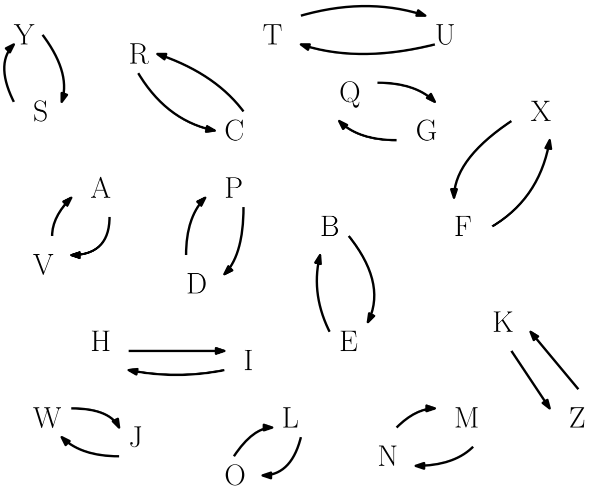

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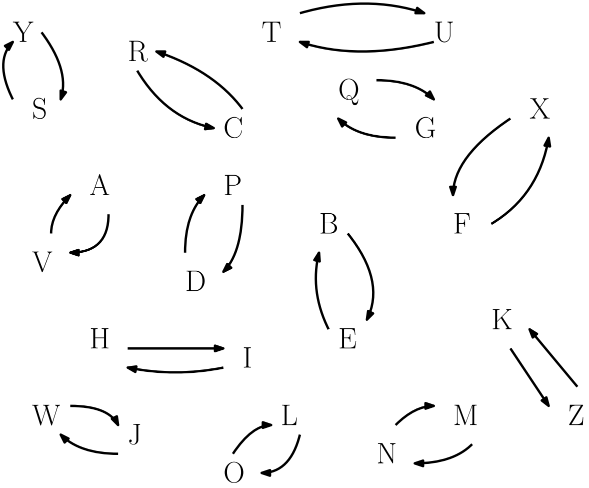

Cycle structure: 2-2-2-2-2-2-2-2-2-2-2-2-2

Cryptanalysis of enigma

Message key: BLA

Encrypted message key (using daily key):

$$\begin{tikzcd}
B \arrow[d, "\sigma_1"] & L \arrow[d, "\sigma_2"] & A \arrow[d, "\sigma_3"] & B \arrow[d, "\sigma_4"] & L \arrow[d, "\sigma_5"] & A \arrow[d, "\sigma_6"] \\
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Learned information about $\sigma_4 \circ \sigma_1$:

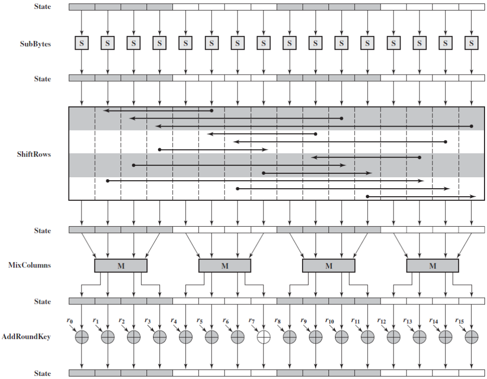
$$A \to W$$

Cryptanalysis of enigma

Bletchley Park Bombe replica

Antoine Taveneaux, CC BY-SA 3.0 https://creativecommons.org/licenses/by-sa/3.0, via Wikimedia Commons

Advent of Computers: AES (Advanced Encryption Standard)



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A new paradigm: public-key cryptography

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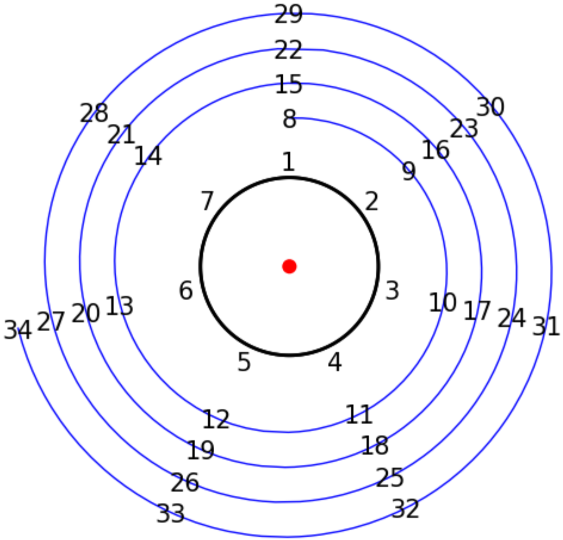
How is this even possible?!

The door to modern cryptography: modular arithmetic



Diffie-Hellman Key Exchange

Setup: p (modulus), g

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Compute: $(g^b)^a \equiv g^{ab}$		Compute: $(g^a)^b \equiv g^{ab}$

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An eavesdropper Eve can see g^a and g^b and must compute g^{ab}.

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For example, to decrypt a message meant for someone else, it may require factoring a number so big, that it is expected to take longer than the length of time before the sun dies.

Warning

We don't actually know they are hard!

Hard Cryptographic Problems

The **Computational Diffie-Hellman Problem**:
Given $g^a, g^b \pmod{p}$, compute g^{ab}.

- Typical algorithms take around $\sqrt{p}$ time.
- Human record: p of 795 bits using 3100 core-years
- Standard internet security: 1024 bits
- Logjam attack: 512 bits attacked in the wild
- (Why did Logjam work? Big swaths of the internet were using the **same prime**!)

RSA: Rivest-Shamir-Adelman

The **Factoring Problem**:
Given an integer $n = pq$ for p and q prime, find p and q.

- Human record: $n \sim 2^{829}$.
- Standard internet security: $n \sim 2^{2048}$.

How big is 2^{2048}?

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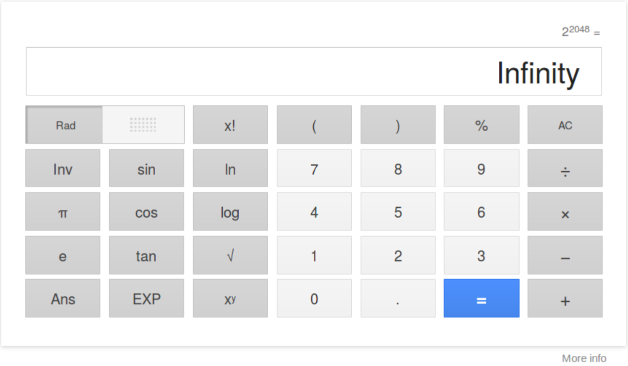

2^{2048} =

Infinity

How big is 2^{2048}?

Estimate each quantity as a power of two (and put them in order!)

- The number of atoms in the universe.
- The number of cells in a human body.
- The number of insects per human on earth.
- The number of seconds until the sun dies.

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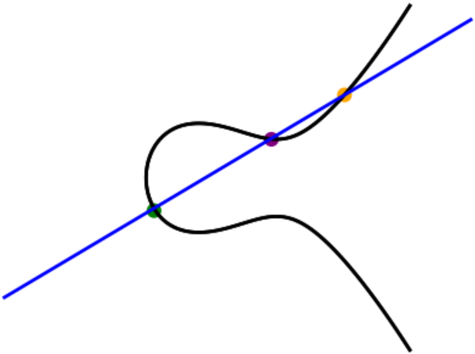
- The number of atoms in the universe: $2^{266} \sim 10^{80} \sim 100$ quadrillion vigintillion.

More modern cryptography: Elliptic Curve Cryptography

Do your computations with a crazy group called an



elliptic curve.

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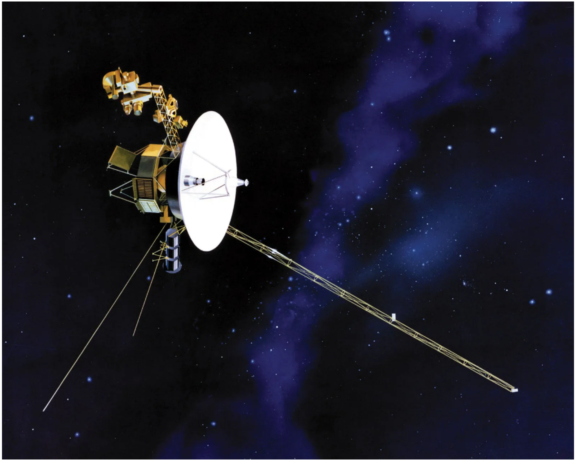
We will study **quantum cryptography**, **quantum algorithms** and **post-quantum cryptography**.



Bonus: Whirlwind tour of coding theory

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  - The receiver must **decode**

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  - Finite fields, linear algebra

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