ÞŐÍTNMAŠTKTNŠ ŠNŁÞSÍTÍNŠAKÕMANÛŁŒKÕONAŁPØØÍŠŠÍPÕ ÚV~ŽæZ*àæDAMÉŁÉAÐËGFÎ

+472 flfi 6

ÃØV^âAPæÝB

A

■ RÞKSTNSÒÜASNQPSTAQÞSŠÞKÕTATPAŠNŁTÓPÕAÈ€APSAÈGÁYBAPÑATŒNAŠNŁÞSÓTÓNŠANÛŁŒKÕONAKŁTAPÑAÈ΀F A

Ñà^*ŽÝAR@V^*Ý^´|AQÝ^ààYANæYÝYAØV^XŽA€ÈDAĐËĐĐA

P^

 $\Box \quad \mathsf{TSK}\tilde{\mathsf{O}}\check{\mathsf{S}}\acute{\mathsf{O}}\mathsf{T}\check{\mathsf{O}}\mathsf{P}\tilde{\mathsf{O}}\mathsf{A}\mathsf{SN}\mathsf{Q}\mathsf{P}\mathsf{ST}\mathsf{A}\mathsf{Q}\mathsf{P}\mathsf{S}\check{\mathsf{S}}\mathsf{P}\check{\mathsf{K}}\tilde{\mathsf{O}}\mathsf{T}\mathsf{A}\mathsf{T}\mathsf{P}\check{\mathsf{A}}\check{\mathsf{S}}\mathsf{N}\mathsf{L}\mathsf{T}\check{\mathsf{O}}\mathsf{P}\tilde{\mathsf{O}}\mathsf{A}\check{\mathsf{E}}\check{\mathsf{G}}\mathsf{A}\mathsf{P}\mathsf{S}\mathsf{A}\check{\mathsf{D}}\check{\mathsf{G}}\mathsf{A}\mathsf{P}\check{\mathsf{O}}\mathsf{N}\check{\mathsf{A}}\mathsf{N}\check{\mathsf{U}}\mathsf{L}\mathsf{E}\check{\mathsf{K}}\tilde{\mathsf{O}}\mathsf{O}\mathsf{N}\mathsf{A}\mathsf{K}\mathsf{L}\mathsf{T}\mathsf{A}\mathsf{P}\tilde{\mathsf{N}}\mathsf{A}\check{\mathsf{E}}\,\check{\mathsf{I}}\,\check{\mathsf{E}}\mathsf{F}$

 $\tilde{N}a^{A}\tilde{Z}^{A}$

Łàääa~~aàæAŸaÝAæ@äWÝ^A**fl`fl!#flfl**



: MHSDC 85@SDR 8SDDK (NQONQ@SHNM

 $\label{eq:linear} \tilde{A} \mathbf{N} \mathbf{V} \mathbf{X}^* \mathbf{A} \mathbf{w} \mathbf{V} \ddot{\mathbf{x}} \dot{\mathbf{x}} \dot{\mathbf{x$

) DK@ V @QD	ł	ł	Łž`fl#\$"flžŁ
ĨĂŠ*V*ÝAà^Aà*ŽÝ^Aá@^a~YaX*aàæAàŸAaæXà^&à^V*aàæB	ł		

QKSTAÓA [AÑÓÕKÕŁÓKÒAÓÕÑPSØKTÓPÕ

Ó*Ý ä AÈÉ	ÑæVæX₂V′ÅŠ*V*Ý ä Ýæ*∼Ï	
	<u>ŁàæYÝæ~ÝY&Łàæ~à´aYV*ÝY&Š*V*Ý ä Ýæ*&àŸ&P&Ý^V*&àæ~&ÅÞæV@Y&*ÝYB</u>	È
	<u>ŁàæYÝæ~ÝY&Łàæ~à´aYV*ÝY&Š*V*Ý ä Ýæ*&àŸ&Łà ä &^ÝŽÝæ~ªãÝ&ÓæXà ä Ý&Óà~~B&Ď₽æV@Yª*ÝYB</u>	Ð
	<u>ŁàæYÝæ~ÝY&Łàæ~à´aYV*ÝY&LV′VæXÝ&ŠŽÝÝ*&ÅÞæV@Ya*ÝYB</u>	<u>€</u>
	<u>ŁàæYÝæ~ÝY&Łàæ~à´aYV*ÝY&Š*V*Ý ä Ýæ*&àŸ&ŁV~Ž&Ñ´àb~&&ÞæV@Ya*ÝYB</u>	E
	<u>Õà*Ý~Å*àÅŁàæYÝæ~ÝYÅŁàæ~à´?YV*ÝYÅŇĩæVæX?V′ÅŠ*V*Ý ä Ýæ*~ÅÅÞæV@Y?*ÝYB</u>	<u>G</u>
Ó*Ý ä AÐÉ	<u>ØVæVZÝ ä Ýæ*~~\M&~X@~~&àæ\VæY\KæV′ ~&~\à'\NĨæVæX&V′\ŁàæY&*&&\VæY\SÝ~@´*~\à'\ P&Ý^V*&àæ~</u>	ĐĐ
Ó*Ý ä A€É	<u>R®Væ*a*V*aāÝAVæYAR®V′a*V*aāÝAMa~X′à~®^Ý~AVWà®*AØV^âÝ*ASa~â</u>	€€
Ó*Ý ä AFÉ	<u>Łàæ*^à´~ĂVæYĂQ^àXÝY@^Ý~</u>	€€
QKSTAÓÓA [APTŒN	ISMŐÑPSØKTÍPŐ	
Ó*Ý ä AÈÉ	<u>ÒÝZV′AQ^àXÝÝYæZ~</u>	€€
Ó*Ý ä AÈKÉ	<u>Sa~âłŇVX*à^~</u>	<u>€Í</u>
Ó*ÝäAÐ	<u>Q@^XŽV~Ý~AàŸANå@a* AŠÝX@^a*aÝ~AW AÓ~~@Ý^AVæYAKŸŸa´aV*ÝYAQ@^XŽV~Ý^~</u>	<u>€Î</u>
Ó*ÝäA€	<u>MÝŸV@′*~4@&àæłŠÝæ;à^4ŠÝX@^s*sÝ~</u>	<u>€Î</u>
Ó*Ý ä AFÉ	<u>ØæÝÅŠVŸÝ*↓ÅMa~X´à~@^Ý</u>	<u>€Î</u>
Ó*Ý ä AGÉ	<u>₽*ŽÝ^4ΰæŸà^ä V*₃àæ</u>	<u>€Î</u>
Ó*Ý ä AHÉ	N\ŽaWa*~	

<u>QVZÝ</u>

:3.9*) 89&9*8 89**1 (47547&9.43 (43)*38*) (43841.)&9*) 89&9*2*39 4+ (4257*-*38.;*.3(42* °:M@TC%DC″



:3.9*) 89&9*8 89**1 (47547&9.43 (43)*38*) (43841.)&9*) 89&9*2*39 4+ (&8-+14<8 °:M@TC%DC″

°) NKK@QR HM LHKKHNMR″	ŁfiŁŁ		ŁfiŁfl
.MBQD@RD °CDBQD@RD″HM B@RG, B@RG DPTHU@KDMSR @MC QDRSQHBSDC B@RG			
4 ODQ@SHMF @BSHUHSHDR%			
ÕÝ*ÅÝV⁄ææZ~	##Ł	ÂA	ÎÈA
KYá@~* ä Ýæ*~&*à&^ÝXàæXa′Ý&*à&æÝ*&XV~Ž&&^àãaYÝY&W &à&Ý^V*aæZ&VX*aãa*aÝ~Ï			
$MÝ$ &^ÝX iV * $ià$ æDiłYÝ& Ý* $ià$ æiłVæYiV ä à^* i {V* $ià$ æ	fl\$#	A	ÈÍÎA
OVækàækÝå@a* AæãÝ~*ÝÝA*^Væ~VX*aàæ~	[A	ÃÈÈÈBA
SÝ~*^@X*@^xæZAVæYAà*ŽÝ^AXŽV^ZÝ~AÅÕà*ÝAĐËB	fl"	A	HA
Òà~~łàæłYÝ₩*łÝ∖*ෲæZ@a~ŽäÝæ*	[A	ÐGGA
QÝæ~&àæ~&VæY&à*ŽÝ^&&à~*^Ý*&^Ý ä Ýæ*&WÝæÝ!»*~	°!fi″	A	ÃÐGBA
MÝŸÝ^^YAæXà ä ÝÅ*V\Ý~ÅÄÕà*ÝÀÈÐB	flŁfl	A	€A
ŐÝ*AZVækàæA~V´ÝAàŸAV~~Ý*~	°٤″	A] A
Nå@a* AaæãÝ~*ÝÝAÝV^æaæZ~DAæÝ*AàŸAYa~*^aW@*aàæ~A^ÝXÝaãÝY	°ł!‴	A	А́ÈFBA
ŁŽVæZÝ~ŀæÏ			
Ł@^^Yæ*ŀ^YXYiāVWY~	°łžž″		Ã fii ba
ĺæãÝæ*à∿ıÝ~	°Ž!"″	A	ÃÈÍ€BA
Ł@^^Ýæ*AVXXà@æ*~A&V VW´ÝAVæYAVXX^@ÝYAÝ\&Ýæ~Ý~	ł ! fifl	#ł″	

TŽÝAŮà´´à þxžZA2~AVA~XŽÝY@´ÝAàŮA^ÝXàæX2'aæZAªÝÄ a~A*àAXàæ~à'aYV*ÝYŽÝM^ææZ~ANŴŶØà^ÝAæ*Ý^Ý~*AVæYAæXà a ÝA*V\Ý~Ï

		9GQDD 2 NM\$GR * MCDC 2 @QBG ∤fl					
°.M LHKKHNMR″	ŁfiŁŁ		ŁfiŁfl				
ĺ*Ý ä ~&æà*&V´´àXV*ÝY&*à&~ÝZ ä Ýæ*~Ï							
SÝ~*^@X*@^%æZAVæYAà*ŽÝ^AXŽV^ZÝ~AÅÕà*ÝAÐËB		fl"″ ÂA	ÃНВА				
P*ŽÝ^¼XŽV^ZÝ~WæÝ*		°Ž″ A	ÃFÐB A				
OV&&~&à&&V~~Ý*~&~à^Y&V&Y&&^Ýãàà@~´ &ŽÝ´Y&&&ãÝ~* ä Ý&*~		E A	ÈÈÈA				
Tà*V′ⅈヘÝXàæXն′æZła*Ý ä ~	~ .	Łfl‴ ÂA	H€A				

žι &BPTHRHSHNMR @MC) HRONRHSHNMR

ÂHĐGA ä zíjaàæA zæA XV~ŽA æÝ*A àľA €HA ä zíjaàæA VæYA ÂHĐA ä zíjaàæA zæA XV~ŽA VæYA ^Ý~*^zX*ÝYA XV~ŽA ^ÝXýzāÝYDA ^Ý~&ÝX*zãÝ(|DA VæYA *ŽÝA V=~@ a &*záæA àľA ízVWzíz*aÝ~AWzíz*a V=~@ a &*záæA àľA ízVWzíz*aÝ~AWzíz*a

AŠ ~V~

₹Xå@a~**Ý≈dát**a~ Ý~ v/*I&ŠXÝãĨÝŠÝ′&*ŽŽÝ& ∛àV

KV# AŠ àn €VĹAY~AŠ

ÝYA

æAæYŠ T

AYA^Y

8

ÒaVWaʿa*aÝ~AK~~@ ä ÝYÏ		
KXXà@æ*~A&V VW'ÝAVæYAVXX^@ÝYA´aVWa´a*aÝ~	ÂA	ÐÐFA
QV ^à´ʿAVæYAWÝæÝŸa*~A&V VW´Ý	A	ÐIA
KXX^@ÝY&*V\Ý~	A	ÎA
KXX^@ÝY&æ*Ý^Ý~*	A	€€Å
ŠŽà^*E*Ý^ä &YÝW*&VæY&X@^^Ýæ*&ä V*@^&*aÝ~&à¾/`àæZE*Ý^ä &YÝW*	A	ÐÎA
ÒàæZE*Ý^ä ÄYÝW*	A	ÈDÎÎIA
$MÝ$ ľÝ^ÝY A&&Xà ä ÝA*V \ A 'aVWa 'a*aÝ~	A	ÐHA
MÝŸÝ^^ÝYAX^ÝYa*~AVæYAà*ŽÝ^A´àæZE*Ý^ ä A´aVWa´a*aÝ~	A	ÐÈÈA
Tà*V´AÒaVWa´a*aÝ~4K~~@ ä ÝY	ÂA	ÐDGGHA
ÑV&^\ÃV´@Ý\àŸ\&^ÝÃ&à@~´ \ŽÝ´YAæãÝ~* ä Ýæ*AækL&ZAS&ãÝ^\Š*ÝÝ´	ÂA	IIËA
Q@^XŽV~Ý&&^&XÝD&&X´@Y&ZAV~~@äÝYA´aVWa´a*aÝ~AVæY&éY*AàŸAXV~ŽAVXå@a^ÝY	A	HIGA
MalīÝÝ YæXÝAaæAV~~Ý*~AVXå@a YAVæYA´aVWa´a*aÝ~AV~~@ ä ÝY	ÂA	ÈDFFGA

!I <u>7 DUDMTD</u>

flfiı <u>5DMRHNMR @MC 4SGDQ 'DMDEHSR</u>

TŽÝAŸà´´àbæZA*VW´ÝA^ÝŸ´ÝX*~A*ŽÝAXà ä &àæÝæ*~AàŸAæÝ*A&Ý^₃àYaXAWÝæÝŸa*AĀæXà ä ÝBAXà~*AŸà^A*ŽÝA*ŽÝA*Ž^ÁYÅ ä àæ*Ž~AÝæYÝYAØV^XŽA€ÈDA ĐËĐĐAVæYAĐËĐÈÏ

	5 DMRHNM 'DMDEHSR			4 SGDQ 'DMDEHSR			
°.M LHKKHNMR″	ŁfiŁŁ		ŁfiŁfl	ŁfiŁŁ		ŁfiŁfl	
ŠÝ^ãaXÝAXà~*	flfl	ÂA	ÈFA ~	Ł	ÂA	€A	
ĺæ*Ý^Ý~*ÅXà~*	ł\$	A	FËA	flŁ	A	ÈÐA	
N\&ÝX*ÝY&^Ý*@^æAàæA&´VæAV~~Ý*~	°#\$″	A	Ã Í Î BA	°ŁŁ″	A	ÂÐËBA	
Käà^*a{V*aàæłàŸł&^aà^ł~Ý^ãaXÝłX^ÝYa*	[A] A	° II ″	A	à I BA	
Käà^*a{V*aàæAàŸAVX*@V^aV′AæÝ*A′à~~AÄZVaæB	fl#	A	€ÍA	° f l∤″	A	ÃНВА	
ÕÝ*A&Ý^3àYaXAWÝæÝŸa*AXà~*AÃaæXà ä ÝBDAÝ\X´@YaæZAWÝ´à b	°Łfl‴	A	€A	°Ł#″	A	ÃÈ Í BA	
Ø@´*aÝ ä&´à Ý^&&`Væ~	fl\$	A	ÈÎA	[A] A	
ŠÝ**´Ý ä Ýæ*D^*Ý^ ä a æV* a àæAVæYAX $@^*$ Va´ ä Ýæ*A´à~~Ý~A ^{Åva}	fl	A] A	[]	
ÕÝ*A&Ý^aàYaXAWÝæÝŸa*AXà~*AÃaæXà ä ÝB \sim	°fl″	ÂA	ĐĐA ~	°Ł#″	ÂA	ÃÈ Í BA	

K~ $\lambda\dot{a}\lambda DV^XZA \in DDDA^{*}a^V/AVa a & Yz^V^{a}a & Yz^{a}a & Yz$

8\$NBJ 4 OSHNMR

 $\dot{\mathbf{z}}$ à a $\dot{\mathbf{z}}$ $\dot{\mathbf{z}}$

flŁı <u>.MBN L D 9@WDR</u>

9@W OQNUHRHNM

Ñà^A+ŽÝA+Ž^ÝYA ä àæ*Ž~A ÝæYÝYA ØV^XŽA€ÈDAÐËÐÐA VæYAÐËÐÈDA*ŽÝAŁà ä &Væ|A^ÝXà^YÝYA VA*V\A&^àãa~aàæAàŸAÂÐFHA ä a′′aàæA VæYAÂÈA

flžı <u>) DAS</u>

°.M L HKKHNMR″	.RRTDQ/'NQQNVDQ	.MSDQDRS 7@SDR	2 @STQHSX	2 @QBG) [BDLADQ∤fl ŁfiŁfl
ÐË€IÅŠÝæià^ÃÕà*Ý~	ÞÉAŠÉAŠ*ÝÝ	HÉHGË	ÐË€I	łžfi	A	€GËA
ÐËÐÍ AŠÝæià^AŠÝX@^ÝYAÕà*Ý~	LaZASaãÝ^AŠ*ÝÝ	HÉHĐG	ÐËÐÎ	"Łfi	A	IÐËA
ÐËÐÎ AŠÝæià^AÕà*Ý~	ÞÉAŠÉAŠ*ÝÝ	HÉÍIG	ÐËÐÎ	"Ž#	A	IGËA
ÐËÐHAŠÝæaà^AŁàæãÝ^*aW′ÝAÕà*Ý~	ÞÉAŠÉAŠ*ÝÝ	GÉËËË	ÐËÐH	łžfi	A	€GËA
Næãảàæ ä Ýæ*V′åSÝãÝæ@ÝåLàæY~	ÞÉAŠÉAŠ*ÝÝ′	FÉÈÐGAEAHÉ I GË	ÐËÐFAEAÐËGË	!Ž"	A	HFIA
NæãảàæäÝæ*V′åSÝãÝæ@ÝåLàæY~	LaZASaãÝ^AŠ*ÝÝ′	FÉGËËAEAFÉ I GË	ÐËFÎ	"žŁ	A	I GÐA
ÑıæVæXÝA´ÝV~Ý~AVæYAV´´Aà*ŽÝ^AàW´aZV*aàæ~	ÞÉAŠÉAŠ*ÝÝ′	UV^₃à@~	ÐËÐÐAEAÐËÐ Î	"Ž	A	HIA
ÑıæVæXÝA´ÝV~Ý~AVæYAV´´Aà*ŽÝ^AàW´aZV*aàæ~	LaZASaãÝ^AŠ*ÝÝ′	UV^₃à@~	ÐËÐÐAEAÐË€È	flŁ!	A	ÈÐÐA
N\&à^*AŁ^ÝYa*AKZ^ÝÝ ä Ýæ*	ÞÉAŠÉAŠ*ÝÝ′	UV^aVW´Ý	ÐË€È	flł!	A	È€HA
Ł^ÝYa*AÑVXa´a* AKZ^ÝÝ ä Ýæ*	ÞÉAŠÉAŠ*ÝÝ′	UV^aVW´Ý	ÐËÐF	[A] A
LaZASaãÝ^AŠ*ÝÝ′AKLÒAÑVXa′a*	LaZASaãÝ^AŠ*ÝÝ	UV^aVW´Ý	ÐËÐH	[A] A
ÞŠŠÖAŁ^ÝYa*AKZ^ÝÝäÝæ*	ÞÉAŠÉAŠ*ÝÝ′AÖà~aXÝ	UV^aVW´Ý	ÐËÐH	[A] A
ÞŠŠÖAŁ^ÝYa*AÑVXa´a*	ÞÉAŠÉAŠ*ÝÝ′AÖà~aXÝ	UV^aVW´Ý	ÐËÐF	[A] A
Tà*V′4MÝW*				ł ָ\$fi ł	A	€DÍÎFA
ÒÝ~~&@æV ä à^*a{ÝY&Y&~Xà@æ*D&&^Ý ä a@ ä D& VæY&YÝW*&a~~@VæXÝ&Xà~*~				°"Ž″	A	€A
ÒÝ~~A~Žà^*E*Ý^ä AYÝW*DA´àæZE*Ý^ä AYÝW*A Y@ÝA ba*ŽaæAàæÝA ÝV^DAVæYA~Žà^*E*Ý^ä A a~~@VæXÝAXà~*~				!fi	A	ÐÍA
ÒàæZE*Ý^ä łYÝ₩*				ັ ∤ູ\$fl"	ÂA	€DÍH€A

LfiL\$ 8DMHNQ 3NSDR

M@^aæZA*ŽÝA*Ž^ÝYÁ ä àæ*Ž~AÝæYÝYAØV^XŽA€ÈDAĐËĐĐDA à&ÝæA ä V^âÝ*A^Ý&@^XŽV~Ý~A b Ý^ÝA ä VYÝA àľAV&&^à \a ä V*Ý′ | AÂĐA ä a ′′aàæA àľA VZZ^ÝZV*ÝA&^aæXa&V′A à aæ*Ž~AÝ&HĖÍ I GÄ AŠÝæa^AGÕà*Ý~AY@ÝAĐËĐÎĖAKæAa ä ä V*Ý^aV′AV ä à@æ*AàľA^Ý&@^XŽV~ÝA&^Ý ä a@ ä A b V~AaæX@^^ÝYA ^Ý V*ÝYA*àA*ŽÝAYÝ&V | ä Ýæ*É

ŁfiŁ! 8DMHNQ (NMUDQSHAKD 3NSDR

‱‰

LaZASaãÝ^AŠ*ÝÝ[·]Á~AV ä ÝæYÝYA~ÁVävàvA~ÝX@^ÝYAV~~Ý*EWV~ÝYAÝāà´ãæZAX^ÝYa*A[†]VXa'á* | AĂLaZASaãÝ^AŠ*ÝÝ[·]ÁKLÒAÑVXa'á* | BA ä V*@^Ý~AàæA Ô@´ | AĐ€DAĐËĐHĖATŽÝA[†]VXa'á* | Aa~A~ÝX@^ÝYAW | A[†]a^~*E&vàà^á* | A'áÝæ~AàæAVXXà@æ*~A^ÝXÝaãVW'ÝAVæYA&æáÝæ*à^ | A/aVæYAXÝ^*VæAà*ŽÝ^AV~~Ý*~A VæYA~ÝXàæYA&^àà^á* | A 'áÝæ~AàæA ä à~*A*VæZaW'ÝA VæYAæ*VæZaW'ÝA V~~Ý*~A à[†]A LaZASaãÝ^AŠ*ÝÝ[·]ÁAæA ÝVXŽA XV~ÝA~@WáÝX*A*àA&Ý^ ä å**ÝYA 'áÝæ~ĖAKYYa*ààæV'´ | DA *ŽÝA V ä ÝæY ä Ýæ*AæX'@YÝ~A~@~*VæVWa'a* | A*V^ZÝ*~A^Ý 'V*ÝYA*àA XV^WàæA^ÝY@X*ààæDA~V[†]Y* | A &Ý^A†à * XæXÝA VæYA ÝVXa'a* | AXÝ^*a[†]aXV*ààæAW | ASÝ-&àæ~aW'ÝŠ*ÝÝ ′ ç É

(

TŽÝA LaZA StáÝ^A Š*ÝÝ A KLÒA ÑVXa'a* | A &^àãaYÝ~A ľà^A Wà^à bæZ~A ľà^A bà^âtæZA XV&a*V'A VæYA ZÝæÝ^V'A Xà^&à^V*ÝA &@^&à~Ý~A tæA VæA VæA bæZa ta va bæXa ta va bæZa ta va bæZa

fl#ı <u>7DBK@RRHEHB@SHNMR EQN L &BBT L TK@\$DC 4 \$GDQ (N L OQDGDMRHUD .MBN L D °& 4 (."</u>

°.M LHKKHNMR″	5 DMRHNI 4 SGDQ ' .SD L	DMDEHS	+NQDHFI (TQQDME .SD L R	3X	: MQD@KHYL °1NRR″,@HM) DQHU@SHU	/ NM		9NS@K
LV′VæXÝAV*AMÝXÝ ä WÝ^A€ÈDAÐËÐÈ	ÂA	ÃÐGB A	ÂA €	IÈA	ÂA	ÃÈGB A	ÂA	€€ÈA
P*ŽÝ^AXà ä &^ÝŽÝæ~ããÝAôà~~BAæXà ä ÝAWÝŸà^ÝA ^ÝX′V~~aŸaXV*aàæ~		°Ł″	٥	Ł#″		flž		°flž″
Käà@æ*~Ѧ^ÝХ′Ѵ~~аў́аÝҮѦў́^àäѦКРŁĺѦ ^{ӑѵ} Ҍ		°fl‴		["		!
ÕÝ*AX@^^Ýæ*E&Ý^aàYAà*ŽÝ^AXà ä &^ÝŽÝæ~aãÝAÅ´à~~BAaæXà ä Ý		°ł″	0	Ł#″		ŁŁ		°\$″
LV′VæXÝAV*AØV^XŽA€ÈDAÐËÐÐ	J	°Ł#″	ĭ ł	Žł	v	"	v	łŁŁ
LV′VæXÝAV*AMÝXÝ ä WÝ^A€ÈDAÐËÐË	ÂA	ÃFG Í BA	ÂA F	FÎA	ÂA	ÀÍBA	ÂA	ÃF I BA
P*ŽÝ^&Xà ä &^ÝŽÝæ~³ãÝ&´à~~&WÝŸà^Ý&^YX´V~~ªŸaXV*ªàæ~	A] A	A Ã	FIBA	A	ÀFBA	A	Ã Í ÈBA

TŽÝAVX*aãa* | AaæA*ŽÝAVXX^@ÝYAWV′VæXÝ~AaæX@^^ÝYAaæA^Ý′V*aàæA*àA^Ý~*^@X*@^aæZAY@^aæZA*ŽÝA*Ž^ÝA*Ž^ÝYA ä àæ*Ž~AÝæYÝYAØV^XŽA€ÈDAĐËĐĐA bÝ^ÝAV~AŸà´´àb~Ï

°.M L HKKHNMR″		KNXDD C (NRSR	* WHS (NRSR	3NM [°] B@RG (G@QFDR	9NS@K
LV′VæXÝAV*AMÝXÝ ä WÝ^A€ÈDAÐËÐÈ	ÂA	ÎÈA ÂA	ÈFÎA ÂA] A ÂA	ÐFËA
KYYa*aàæV′AXŽV^ZÝ~		fl#	°fl‴	[fl"
ŁV~Ž&&V∣äÝæ*~Ė@*a′a{V*aàæÅ ^{ĬVB}		° II ‴	°Łfl‴	[°Ł#″
LV′VæXÝAV*AØV^XŽA€ÈDAÐËÐÐ	U	flfiŁ ~	flŁ" ˘	[Ŭ	ŁŁ\$

ĀVB ÂGĂā 3 (2) à X & V Y A A VYÝA A VYÝA A A X Y X A A A X X A A X A A X A A X A A X X A X X A X A X A X A X A X A X X A X A X A X A X A X A X A X A X A X A X X A X A X X A X A X A X A X X A X X A X X A X X A X A X X A X A X X A X X X A X X X X X A X X X X X

KXX^@ÝYA′aVWa′a*aÝ~AŸà^A^Ý~*^@X*@^aæZA&^àZ^V ä ~AV^ÝAaæX′@YÝYAaæA*ŽÝAŸà′´à baæZAWV′VæXÝA~ŽÝÝ*A′aæÝ~Ï

°.M L HKKHNMR″		2@QBG łfl ŁfiŁŁ)[DBDLADQ łfl ŁfiŁfl
KXXà@æ*~A&V VW'Ý	J	łfi	ÂA	€FA
QV ^à´´AVæYAWÝæÝŸa*~A&V VW´Ý		fl	A	ÐA
Nä&´à ÝÝѦѠÝӕÝѷ҈҂~		flfifl	A	ÍÍA
ΜΫ́Ϋ́Υ̣̣̣̣̣̣̣̣̣̣̣̣̣̣̣̣̣̣̣̣̣̣̣̣̣̣̣̣̣̣̣̣		\$!	A	ÈÈHA
Tà*V′	J	ŁŁ\$	ÂA	ÐFËA

Łfli <u>(NMSHMFDMBHDR @MC (NLLHSLDMSR</u>

ÞÉA ŠÉA Š*ÝÝ´A a~A *ŽÝA ~@WáÝX*A àŇDA à^A &V^*|A *àDA VA æ@ ä WÝ^A àŇA &ÝæYaæZA à^A *Ž^ÝV*ÝæÝYA ´ÝZV´A VX*aàæ~DA Xàæ*aæZÝæXaÝ~A VæYA Xà ä ä a* ä Ýæ*~Aaæãa´ãaæZAVAãV^aÝ*|AàŇA ä V**Ý~-DAaæX´@YaæZA`V D~AVæYA^ÝZ@´V*aàæ~A^Ý`V*aæZA*àA*ŽÝAÝæã^àæ ä Ýæ*ÉAŁÝ^*VaæAaŇA*ŽÝ~ÝA

à&Ý^V*aàæAàÝA*ŽÝAŸVXa′a* |ÉATŽÝ~ÝAæXÝæ*a≦Ý~AXàæ~a~*AàÝAVYãVæXÝA′@ ä &E~@ ä A&V | ä Ýæ*~A bŽaXŽAV^ÝAæXY@YÝYAæAYÝŸÝ^^ÝYAX^ÝYa*~A VæYAà*ŽÝ^AæàæX@^^Ýæ*A′aVWa′a*aÝ~AàæA*ŽÝAXàæYÝæ~ÝYAXàæ~à ′aYV*ÝYAWV′VæXÝA~ŽÝÝ*ÉAÓæAØV^XŽAĐËĐĐDA*ŽÝAŁà ä &Væ | A^ÝXÝaãÝYAVA '@ ä &E~@ ä A&V | ä Ýæ*AàÝAV&&A`a a V*Ý | A Í ĐA ä a′ aàæAĬ^à ä A&^àXÝÝY~Aľ^à ä A*ŽÝA~V´ÝAàŸA*V \AX^ÝYa*~A@æYÝ^A*ŽÝAŠ*V*ÝAàŸAK^âVæ~V~Å~A SÝX | X′æzZA TV\A Ł^ÝYa*A ĀSTŁBA &^àZ^V ä ÉA TŽÝ~ÝA Ÿ@æY~A V^ÝA *àA WÝA @~ÝYA &^a ä V^a′ | A Ÿa^A *ŽÝA VXå@a~a*aàæA àŸA &^àiÝX*A ^Ý 'U*ÝYA Ýå@a& ä Ýæ*DAŽà bÝãÝA*ŽÝ | A ä V | AV ′~àAWÝA@~ÝYAĬÀa^*ŽÝA*V Yæ&YAYÝâÝ 'à& ä Ýæ*AàŸAæY bAÝ ä & `a | ÝÝ~AŽa^ÝYAĬà^A*ŽÝA&OàiÝX*ÉATŽÝA Łà ä &Væ | A a~A Xàæ*æZÝæ*′ | A ´aVWÝA Ŷa^A XŹÝ*VæAA*ŽÝA* &ÝæY *a &Ýæ Vá a ÝA a aľA *ŽÝA Łà ä &Væ | A ÌVá ′~A *àA ä ÝY* AXÁ*VæA Ý ä & `a | á Ýæ*A

4 UDQUHD V

$$\begin{split} \tilde{N}a^{A}^{*}Z'A^{*}Z'A'YA^{*}Z'A$$

	9GQDD 2 NMSGR	* MCD	C 2@QBG łfl					
°) NKK@QR HM LHKKHNMR, DWBKTCHMF HMSDQRDFLDMS R@KDR″	ŁfiŁŁ		ŁfiŁfl	(G@MFD				
Ñ′V*ESà′′ÝYAQ^àY@X*~AÅÑ′V*ESà′′ÝYB	َ	ÂA	ĐDĐ I ĐA	ÆËÅÄ				
ØaæaAØa ´´A ^{ÄVB}	"fl#	A	FGËA	H ËA Ä				
ÞÉAŠÉAŠ*ÝÝ′AN@^à&ÝAÅÞŠŠNB VX^à~~A&^àØ @ X * ~	DA& V fl,Łžfl	A	IÎÍA	ĢIĄÄ	χ ^ ý V	~		
T@W@'V^AQ^àY@X*~AĂT@W@'V^B	łfi\$	A	È€FA	È€ÈÃÄ		~	~	
₩₩₩Ŧà*V´&~V´Ý~&Ÿ^àä&^^Ý&à^*VW´Ý&~ÝZäÝæ*~	ž,ŁłŁ	A	€DHGFA	F€AÄ				
P*ŽÝ^	Ł	A	ÈËA	Ã Í ËB⁄Ä				
ÕÝ*Å~V´Ý~	ž,ŁłŽ	ÂA	€DHHFA	F€AÄ				

ä

^{ĂV®}ĂØġæġĂØġ´´Ă~ÝZ ä Ýæ*ĂVYYÝYĂVŮ*Ý^ÁÔVæ@V^|ĂÈGDĂĐËĐĖĂĐġ*ŽĂ*ŽÝĂ&@^XŽV~ÝĂĂŮĂ*ŽÝĂ^Ý ä VæġæZĂÝå@ġ*|*Ă*ġæ*Ý^Ý~*ĂœĂLġZKSąãÝ^KŠ*ÝÝÉ

ØVæVZÝ ä Ýæ*~AVæV′ | ~a~A àŸA*ŽÝA ODQBDMS@FD BG@MFD HM MDS R@KDRAŸà^A ÞÉA ŠÉA Š*ÝÝ′~A^Ý&à^*VW′ÝA W@~aæÝ~~A ~ÝZ ä Ýæ*~AŸà^A*ŽÝA*ŽÝA*Ž^ÝÝA ä àæ*Ž~AÝæYÝYAØV^XŽA€ÈDAĐËĐĐAãÝ^~@~A*ŽÝA*Ž^ÝYA ä àæ*Ž~AÝæYÝYAØV^XŽA€ÈDAĐËĐÈAa~A~Ý*AŸà^*ŽAaæA*ŽÝAŸà ′`à baæZA*VW′ÝÏ

	; NKT L D	5QHBD	2 HW	&BPTHRHSHNM ; @QH@MBD	+= ^{°A″}	4 \$GDQ ^{°B″}	3D\$ (G@MFD
Ñ′V*ESà′′ÝY	Ä ÈGB#Ä	F ÈA Ä	A] AÄ	æÊV	A] AÄ	ÆĂÄ	ÐÎAÄ
ØaæaAØa´´A ^{ÄYB}	Ã Í BAÄ	F ÈA Ä	A] AÄ	ÐHA Ä	A] AÄ	ÈAÄ	h ëa ä
ÞŠŠN	ALA Ä	GÍAÄ	A] AÄ	æÊV	Ã Í BAÄ	A] AÄ	GI AÄ
T@W@ <i>`</i> V^	F ËA Ä	AÎ HA Ä	ÀBÄ	æÊV	A] AÄ	ÃĐ₿#Ä	È€È≬Ä

^{ĀVB}AA**N**\X´@YÝ~Aaæ*Ý^~ÝZäÝæ*A~V´Ý~É

^{ĂWB}AA**Ñà^Ý**aZæAX@^^ÝæX|A*^Væ~´V*aàæAÝŸŸÝX*~É

 $^{\rm AXB}$ AAQ^9 ä V^8′ | AàŸA~V′Ý~AàŸA^V b A ä V*Ý^8V′~AVæYAXàâÝA ä Vâ
aæZAW | E&^àY@X*~É

^{ĂV®}ĂØæ&ĂØĭĨĂ~ÝZ Ä Ýæ*ĂVYYÝYĂVŸ*Ý^ÅÔVæ@V^|ĂĖGDĂĐËĐĖĂb\$*ŽĂ*ŽÝĂ&@^XŽV~ÝÀÀĬÅ*ŽÝÅ^Ý Ä Væ&æZĂÝÅ©&*|Å&#*Ý^Ý~*%&&L&ZAS&ÄÝ^ÅŠ*ÝÝ'É

ŐÝ*Å~V′Ý~ÅŸà^Å*ŽÝÅ*Ž^ÝÝÅ ä àæ*Ž~ÅÝæYÝYÅØV^XŽÅ€ÈDÅÐËÐÐÅXà ä &V^ÝYÅ*àÅ*ŽÝÅ~V ä ÝÅ&Ý^ààYÅæÅÐËÐÈÅ b Ý^ÝÅÂGDЀFÅ ä á″aàæÅVæYÅ€DHHFÅ ä á″aàæDÅ^Ý~&ÝX*aãÝ′ [É

- c Ñà^Ѧ*ŽÝѦŃŹY*ESà″ÝYA~ÝZäÝæ*Å*ŽÝѦӕӾヘÝV~ÝѦӕѦ~ѴΎ~Ѧ&^яäV^я`JѦ^Ý~@´*ÝYÅŸ^àäѦŽ₃ZŽÝ^ѦѴãÝ^VZÝѦ^ÝV′ã{ÝYA&^3XÝ~ÅÅÂFÍËѦ&Ý^Ѧ*àӕѲѦ VX^à~~A&^àY@X*~DA&V^*aV″ JAàŴ~Ý*AW JAYÝX^ÝV~ÝYA~Ž₃&äÝæ*~AÀÍGA*Žà@~VæYA*àæ~BAVX^à~~Aäà~*A&^àY@X*~É
- c Ñà^h*ŽÝAØææAØa´´A~ÝZ ä Ýæ*A*ŽÝAæ&X^ÝV~ÝAæA~VÝ~A&^a ä V^a´ | A^Ý~@´*ÝYAÝ^à ä AŽaZŽÝ^A^ÝV´a { ÝYA &^aXÝ~AÂÂFËGA&Ý^A*àæBAVX^à~~AV´´A &^àY@X*~A VæYA æX^ÝV~ÝYA ~Ža& ä Ýæ*~A ÃHËA *Žà@~VæYA *àæ~BA V~A VA ^Ý~@`*A àÝA *ŽÝA &V^*aV´A &Ý^aàYA àÝA *ŽÝA Łà ä &Væ | Å~A Xàæ*^à´`ææZA æ*Ý^Ý~*AæALaZASaãÝ^AŠ*ÝÝ ´AæARÈAĐËĐÈÉ

С

ÓæAMÝXÝ ä WÝ^AÐËÈÎDAÞÉAŠÉAŠ*ÝÝ 'AVææà@æXÝYA*ŽV*Aª*A bà@´YAæYÝŸææª*Ý | AªY´ÝAVA~ªZædŸaXVæ*A&à^*aàæAàŸAO^ÝV*AÒVâÝ~A Ú à^â~AY@ÝA*àA ä V^âÝ*A XàæYa*aàæ~A aæX´@YæZA Xàæ*aæ@ÝYA ŽaZŽA ´ÝãÝ´~A àŸA a ä &à^*~ÉA TŽÝAŁà ä &Væ | A WÝZVæA aY´aæZA*ŽÝA a^àæA VæYA ~*ÝÝ´ ä VâaæZA ŸVXa′a*aÝ~A aæA ØV^XŽA ĐËĐËAVæYA*ŽÝAŽà*A~*^a&A ä a´´A^à´´aæZAŸVXa´a* | AaæAÔ@æYAÐËÐËÉ

bahDËDËDA b ÝA*ààâAVX*aàæ~A*àAVYá@~*àà@^A\Ÿàà*&^sæ*AW|AaY`sæZAXÝ^*VsæAà&Ý^V*sàæ~A*àAWÝ**Ý^AV´sZæA&^àY@X*sàæAba*ŽAX@~*à ä Ý^AYÝ ä VæYAVæYA ^Ý~&àæYA*àA*ŽÝAa ä &VX*~A\Ŷaà ä A*ŽÝA Ł PUÓMEÈ Î A&VæYÝ ä sXÉATŽÝAà&Ý^V*sàæ~A*ŽV*A b Ý^ÝAsæs*sV´´|AaY´ÝYAsæAĐËĐËAVæYA^Ý ä VsæÝYAaY`ÝAV~AàÝA ØV^XŽA€ÈDAĐEĐĐAsæX´@YÝYI ä VsæÝYAaY`ÝAV~AàÝA ØV^XŽA€ÈDAĐEĐĐAsæX´@YÝYI

- c $L'V \sim A\tilde{N}@ \sim VXYAKAV AO^V aa YALa | AUa^a ~$
- c ÒàæÝAŠ*V^AT@W@´V^AP&Ý^V*aàæ~
- c Òà^VaæAT@W@´V^AP&Ý^V*aàæ~
- c ÚŽÝÝ íæZŁØVXŽæÝŁQ^àY@X*~ŁXà@& íæZŁ&^àY@X*aàæŁŸVXa ía* | ŁV*ŁŒ@ZŽÝ~ŁŠ&^&&Z~DŁTÝ\V~

K~AàŸAØV^XŽA€ÈDAÐËÐÐA*ŽÝAXV^^| 2æZAãV′@ÝAàŸA*ŽÝA2Y´ÝYAŸa\ÝYAV~~Ý*~AŸà^AŸVX3′3*3Ý~Aæà*ÝYAVWàãÝAÐV~ÏAO^Væ3*ÝAŁ3*|AÚà^â~AL´V~*AÑ@^æVXÝA KDAÂHËA ä a″aàæÌAÒàæÝAŠ*V^AT@W@´V^A₽&Ý^V*aàæ~DAÂGA ä a″aàæÌAÒà^VaæAT@W@´V^AP&Ý^V*aàæ~DAÂHGA ä a″aàæAVæYAÚŽÝÝ′aæZAØVXŽ3æÝAQ^àY@X*Å~A &^àY@X*aàæAŸVXa′á*|DAa ä ä V*Ý^aV′É

ÓæA MÝXÝ ä WÝ^A ĐËĐÈDA *ŽÝA Łà ä &Væ | A &Ý^ ä VæÝæ*′ | A aY 'ÝYA *ŽÝA ~*ÝÝ′ ä VâæZA à&Ý^V*aàæ~A V*A a*~A O^ÝV*A ÒVâÝ~A Úà^â~A ŸVXa'a* |ÉA TŽÝA Xàa'A Ýaæa~ŽaæZA&^àXÝ~~AXàæ*aæ@Ý~A*àAà&Ý^V*ÝAVæYA*ŽÝAa^àæA ä VâaæZA&^àXÝ~~AV*AO^ÝV*AÒVâÝ~A Úà^â~A^Ý ä Vaæ~AaY 'ÝYAŸà^AVæAa@YÝŸaæa*ÝA&Ý^aàYA àŸA*a ä ÝÉATŽÝAXV^^ | aæZAãV´@ÝAàŸA*ŽÝA^Ý ä VaæaæZAO^ÝV*AÒVâÝ~A Úà^â~AaæYÝŸaæa*Ý′ | AaY 'ÝYAŸVA'a*aÝ~A b V~A&&^à \a ä V*Y´ | AÂÈGGA ä i´aàæAV~AàŸA ØV^XŽA €ÈDA ĐËĐĐÉA ÓæA VYYa*aàæDA aæA ØV^XŽA ĐËĐĐDA *ŽÝA Łà ä &Væ | A &Y^ ä VæÝæ*′ | A aY 'ÝYA *ŽÝA Ÿaæa~ŽaæZA ŸVXa'a*aÝ~A V*A a*~A NV~*A ŁŽaXVZàA TaæA à&Ý^V*aàæ~DA DŽaXŽAŽVYAWÝÝækaY 'ÝYAàæAVæAa&YA'Ÿawa*YAWV~a~AY@^aæZAĐËÈÎĖ

* @QMHMFR °KNRR″ ADENQD HMSDQDRS @MC HMBN L D S@WDR W | A~ÝZ ä Ýæ*Aa~A~Ý*AŸà^*ŽAæA*ŽÝAŸà''à bæZA*VW'ÝÏ

	9GQDD L NMSGR DMCDC 2 @QBG If			
ÂMà´´V^~AaæA ä a´´aàæ~B		ŁfiŁŁ	ŁfiŁfl	(G@MFD
Ñ′V*ESà′′ÝY	v	žflł Â A	ÈFHA	ÐGÈAÄ
ØaæaAØa´´A ^{ÄVB}		Ł"# A	È€ÐA	È ÈÈA Ä
ÞŠŠN		Ł!Ž A	ÈËGA	È GÈA Ä
T@W@´V^		"" A	ÃĐ Î BA	€HHAÄ
Tà*V′ѦÝV^æıæZ~Ѧѷ^àӓѦ^Ý&à^*VѠ′ÝѦ~ÝZӓÝӕ*~		flĮflłŁ A	€GFA	ÐÐËAÄ
P*ŽÝ^		" A	ÍA	ÃÈ€BÄ
ŠÝZ ä Ýæ*AÝV^æaæZ~AWÝŸà^ÝAaæ*Ý^Ý~*AVæYAaæXà ä ÝA*V\Ý~		fl _t fl∤\$ A	€HÐA	ÐÈGA Ä
ĺ*Ý ä ~ŀæà*ŀV´´àXV*ÝYŀ*àŀ~ÝZ ä Ýæ*~Ï				
SÝ~*^@X*@^3æZAVæYAà*ŽÝ^AXŽV^ZÝ~	A	ÃÈ I BAA	ÃНВА	
P*ŽÝ^AXŽV^ZÝ~DAæÝ*	A	Ã ⊢ BAA	Ã F ÐBA	
OV&æ~AàæAV~~Ý*A~à´YAVæYA&^Ýãaà@~´ AŽÝ´YA&æãÝ~* ä Ýæ*~	A] A A	ÈÈÈA	
Tà*V′ÅÝV^ææZ~&WÝŸà^Ý&æ*Ý^Ý~*&VæY&æXà ä ÝÅ*V\Ý~	v	fi _t fifi# ÂA	FÐGA	ÈH€AÄ

^{ĂV®}ĂØææĂØa´ĨĂ~ÝZ ä Ýæ*ĂVYYÝYĂVŸ*Ý^ÅÔVæ@V^|ÅĖGDĂĐËĐĖĂЬa*ŽĂ*ŽÝ&&@^XŽV~ÝÀàŸÅ*ŽÝÅ^Ý ä VæææZAÝå@a*|*Åæ**Ý^Ý~*&&æÅLaZÅSaãÝ^ÅŠ*ÝÝ É

8DF L DMS QDRTKSR ENQ +K@S 7NKKDC ZZ

žŽ

	9GQDD L NMSGR DMCDC 2 @QBG łfl			
		ŁfiŁŁ	ŁfiŁfl	(G@MFD
$NV^{sta}Z$ ~AWÝÝà^ÝAæ*Ý^Ý~*AVæYA*V\Ý~AÅÂA ä a ´´aàæ~B	ÂA	GÈ€A ÂA	ÈFHA	Ð GÈA Ä
O^à~~A ä V^Zaæ		ЀAÄ	È GA Ä	AÍ A Ä
SVbA~*ÝÝ′A&^àY@X*aàæAÁ ä æ*B	A	ÐDÐËGA A	ÐDG Í ÈA	ÃÈGB #Ä
とV&VWa'a* A@*a'a{ V*aàæ		Ħĺ∆Ä	H ĐA Ä	HAÄ
Š*ÝÝ′A~Ž2& ä Ýæ*~AÃ ä æ*B	A	ÈDÎFIA A	ÐD€€ÐA	ÃÈ I BAÄ
KãÝ^VZÝ&^ÝV´a{ÝY&~*ÝÝ´&&^aXÝ&&Ý^*àæ	ÂA	ÈD€HÍA ÂA	ÍÍÍA	GFA Ä

ŽÝ~Ý&XŽVæZÝ~&bÝ^Ý&V^&V´´|&àŸĬ~Ý*&W|Ï

- c YÝX^ÝV~ÝYA~Ža&ä Ýæ*~AÃV&&^à\a ä V*Ý ′ | AÂ Î GA ä a ′´aàæB
- c $\tilde{Z}_{a}Z\tilde{Z}Y^{A}V bA \ddot{a} V^{*}Y^{a}V^{A}X\dot{a}^{*} \sim A\tilde{A}V \& A^{\dot{a}} \dot{a} V^{*}Y^{\prime} | A\hat{A}\dot{E}HGA \ddot{a} a^{\prime\prime}a\dot{a} \& B$
- $\tilde{Z}_{a}Z\tilde{Z}Y^{A}\tilde{Y}_{a}\tilde{Y}^{A}$
- c $aa X^{Y}V \sim YAa \dot{Y}^{V*a} ZAXa^{*} \sim AA V & A^{a} \dot{a} \dot{a} V^{*}Y' | AA \dot{E} I GA \ddot{a} a' a \dot{a} a B$
- c Ž₃ZŽÝ^Aà*ŽÝ^AXà~*~A&^ÝYà ä ₃æVæ*´ | AãV^₃VW/ÝAXà ä &Ýæ~V*ààæAÅV&&^à \ ₃ ä V*Ý´ | AÂÈ€GA ä ₃´´ààæBÉ

O^à~~# ä V^Zæ&ľà^#ŽÝ#*ŽÝ¥Ž^ÝÝ# ä àæ*Ž~#ÝæYÝY#ØV^XŽ#€ÈD#ĐËĐĐ#Xà ä &V^ÝY#*à#*ŽÝ#~V ä Ý#&Ý^®àY#æ#ĐËĐÈ#æX^ÝV~ÝY#&^® ä V^9′ | #V~#V#^Ý~@´*#àŸ# ŽaZŽÝ^#VāÝ^VZÝ#^ÝV′a{ÝY#&^9XÝ~É

8DF L DMS QDRTKSR ENQ 2 HMH 2 HKK ""

	9GQDD 2 NMSGR * MCDC 2 @QBG łfl			
	ł	ĹfiŁŁ	ŁfiŁfl	(G@MFD
NV^æ&æZ~&WÝŸà^Ý&æ*Ý^Ý~*&VæY&*V\Ý~&ÅÂ&ä&´`& a æ~B	ÂA	ÐIÍA A	È€ÐA	È ÈÈA Ä
O^à~~A ä V^Zæ		I FHA Ä	€HAÄ	ÈËAÄ
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とV&VWa´a* A@*a´a{ V*aàæ		AI FA Ä	AI GA Ä	ÃÈB/Ä
Š*ÝÝ′A~Ža&äÝæ*~AÄäæ*B	A	GËIA A	FFIA	È€AÄ
ΚãÝ^VΖÝѦ^ÝV′ã{ÝΥѦ~*ÝÝ′Ѧ&^҈XÝѦ&Ý^Ѧ*àæ	ÂA	ÈD€IÐA ÂA	ÎHIA	i FÐA Ä

 AV8 hØ3æ4hØ3´´h~ÝZ ä Ýæ*hVYYÝYhVÍ*Ý^HÔVæ@V^| hÈG14ĐËĐÈhb3*Žh*ŽÝh&@^XŽV~ÝhàÝh*ŽÝh^Ý ä V3æ3æZhÝå@3* | h3æ*Ý^Ý~*h3æhL3ZhSåãÝ^HŠ*ÝÝÉ

TŽÝAæX^ÝV~ÝAæAØæaAØa′′A^Ý~@′*~AŸà^A*ŽÝA*Ž^ÝYA ä àæ*Ž~AÝæYÝYAØV^XŽA€ÈDAĐËĐĐAXà ä &V^ÝYA*àA*ŽÝA~V ä ÝA&Ý^aàYAæAĐËĐÈAb V~A&^a ä V^a′ |A Y@ÝA*àÏ

- *ŽÝ~ÝAXŽVæZÝ~AbÝ^ÝA&V^*aV´´|AàŸŸ~Ý*AW|Ï
 - c $\tilde{Z}_{a}Z\tilde{Z}Y^{A}V b A \ddot{a} V^{*}Y^{a}V A X\dot{a} \sim^{*} A \tilde{A}V \& A^{\dot{a}} a \ddot{a} V^{*}Y' | A \hat{A} I G A \ddot{a} a \tilde{a} a \tilde{a} a B$
 - c $\frac{1}{2} \frac{1}{2} \frac{$
 - c $Z_{3}ZZY^{A}Y_{x}Y_{x}^{A}Xa^{*}AAV&^{a} a V'Y' AAGA a a'a'aaeB$
 - c ŽaZŽÝ^kà*ŽÝ^kXà~*~D4&^a ä V^a′ | AãV^aVW[°]ÝAXà ä &Ýæ~V*aàæAÃV&&^à \ a ä V*Ý′ | A€Ëk ä a ′′aàæBÉ

 $O^{a} \sim A \ddot{a} V^{Z} a \dot{a} \dot{a}^{A} \dot{z} \dot{A}^{A} \dot{z} \dot{A}^{A} \dot{z} \dot{A}^{A} \dot{z}^{A} \dot{A}^{A} \dot{z}^{A} \dot{A}^{A} \dot{z}^{A} \dot{A}^{A} \dot{z}^{A} \dot{A}^{A} \dot{z}^{A} \dot{A}^{A} \dot{z}^{A} \dot{z$

O^à~~& ä V^Zæ&l^à^*ŽÝ&^{*}Ž^Ý&^{*}Ž^&Ý&#YÝY&ØV^XŽ&€ÈD&ĐËĐĐAXà ä &V^ÝY&*à&*ŽÝ&~V ä Ý&**8%%%**AP&æ&DËĐÈ&æX^ÝV~ÝY&&^a ä V^a´|&V~&V**!NË**~@ÑàŸ& ŽaZŽÝ^&VŽÝ&VŽÝ&^ÝY&{Y&&^aX[®]XÝ~&VæY&~VÝ~&ãà`@ ä ÝÉ

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$NV^{a}Z^{\dot{c}\dot{A}'\dot{a}}$ ~BAWÝŸ \dot{a} AÝAzæ*Ý^Ý~*AVæYA*V\Ý~AÅÂA ä a ´´aàæ~B	ÂA	IIA ÂA	ÃĐ Î BA	€HHAÄ
O^à~~∦ä V^Zıæ		ÐÎAÄ	ÃÈÈB /Ä	FËAÄ
SVbA~*ÝÝ′A&^àY@X*aàæAÃ ä æ*B	A	ÈGHA A	΀A	HÍAÄ
ŁV&VWa´a* A@*a´a{V*aàæ		AI ËA Ä	F ÐA Ä	ÐÍAÄ
Š*ÝÝ ′A~Ž&& ä Ýæ*~AÅ ä æ*B	A	ÈÐÍA A	ÍÎA	F FA Ä
KãÝ^VZÝ&^ÝV′a{ÝY&~*ÝÝ′&&^aXÝ&&Ý^&*àæ	ÂA	ÐD€FÎA ÂA	ÈD€∣ÐA	A ÈA Ä

TŽÝłaæX^ÝV~ÝľaæAT@W@′V^A^Ý @^{**}~AYà^{*}A*Ž^{*}YT TŽÝłaæX^ÝV~ÝľaæAT@W@′V^A^Ý~@^{**}AYà^{*}A*Ž^{*}YYł ä àæ*Ž~AÝæYÝYłØV^XŽł€ÈDłĐËĐĐAV~AXà ä &V^ÝYł*àł*ŽÝł~V ä Ýł&Ý⁄₃àYłaœłĐËĐÈłàXX@^^ÝYł YÝ~&a*ÝAXàæ*æ@ÝYŀŽ₂ZŽłÝãÝ′~AàŸła ä &à^*~AVæYAb V~A&∿a ä V∿á′ | AY@Ýł*àÏ

c ﷺX^ÝV~ÝYAVãÝ^VZÝA^ÝV′a{ÝYA&^xXÝ~DAæX´@YæZAäa\ÅÄV&&^à\aäV*Ý´|AÂÈËËAäa´´aàæB

c ﷺX^ÝV~ÝYA~Ža& ä Ýæ*~DA掴@YaæZAãà´@ ä ÝAÝŴaXaÝæXaÝ~AĀV&&^à \a ä V^{*}Ý´ | AÂÈGA ä a´´aàæB

c à**ă**@^

3DS (@RG 5QNUHCDC AX 4ODQ@SHMF &BSHUHSHDR

ÕÝ*AXV~ŽA&^àãaYÝYAW|Aà&Ý^V*aæZAVX*aãa*aÝ~AbV~AÂIIÈA ä a ′′aàæAÅà^A*ŽÝA*Ž^ŶÝA ä àæ*Ž~AÝæYÝYAØV^XŽA€ÈDAĐËĐĐAXà ä &V^ÝYA*àAæÝ*AXV~ŽA &^àãaYÝYAW|Aà&Ý^V*aæZAVX*aãa*aÝ~A àŸAÂÈÈÈA ä a ′′aàæA aæA*ŽÝA~V ä ÝA&Ý^aàYA aà# DËĐÈÉA TŽÝA &Ý^aàYA àãÝ^A &Ý^aàYA aæX^ÝV~ÝA aà& $A^{a}aaA$ à&Ý^V*aàæ~A bV~A&^a ä V^a`|AY@ÝA*àA~*^àaæZÝ^A ŸaæVæXaV´A^Ý~@´*~A VæYAaæX^ÝV~ÝYA*V\Ý~A&V|VW′ÝDA&V^*aV´|AàŸA &Á XV&a*V'ÉAŁŽVæZÝ~AaæA bà^âaæZAXV&a*V'AXVæAãV^|A~aZæ3³aXVæ*'|AYÝ&Ýa¥YaæZAàæA[†]VX*à^~A~@XŽAV~A*aŽÝA*a ä aæZAàŸAaæãÝæ*à^|A&^à2@X*àæAVæYA &@^XŽV~Ý~DA bŽaXŽA a~A VŸÝYAW|A*ŽÝA [†]YaZ*ŽAà¾A à@^A W@~aæÝ~~A X|X´Ý~A V~A bÝ´A V~A à@^A XV&*aãÝA VbA ä V*Ý^aV´~A &à~a*aàæDA X@~*à ä ÝA &V| ä Ýæ*~Aà³AVXXà@æ*~A^ÝXYaZWÝA&ZYA&AV| ä Ýæ*~A*àAãÝæYà^~AaæAŽÝA^YZ@′V^AXà@^~ÝAà[®]AW@~aæÝ~~É

K~A~Žà bæAWÝ ´à b Aà@^AXV~ŽAXàæãÝ^~aàæAX | X ´ÝAŸà^A*ŽÝAŸa^*Aå@V^*Ý^AàŸAĐËĐĐAaæX^ÝV~ÝYAW | AŸaãÝAYV | ~AV~AXà ä & V^ÝYA*àA*ŽÝAŸà@^*ŽAå@V^*Ý^A àŸAĐËĐÈA&^a ä V^a´ | AŸ^à ä AaæX^ÝV~ÝYAaæãÝæ*à^ | AYV | ~AY@ÝA*àAaæX^ÝV~ÝAaæA^V b A ä V*Ý^aV´AaæãÝæ*à^ | É

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KXXà@æ*~&^ÝXÝsãVW′ÝD&æÝ*& ^{Åvb}	ÂÐDFÈG	€Î	ÂÐDË Í Î	€١
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^{Ŵ®#}ŁV´X@´V*ÝYAV~#KãÝ^VZÝ4KXXà@æ*~ASÝXÝ3ãVW´ÝD&æÝ*AY3ã3YÝYAW|A*à*V´4ÕÝ*ÅŠV´Ý~A ä @´*3&´3ÝYAW|A*ŽÝAæ@`äWÝ^AàŘAYV|~*k*3æ#*ŽÝA&Ý^3àYÉ

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^{1X88}上VX® V*ÝYAV~4KãÝ^VZÝ4KXXà®æ'~AQV|VWÝ4VæYAP*ŽÝ^4KXX^®ÝYAÒ2VW3'à*àY~A Ý~^{*}AWVæðAXŽÝXâ~Aà®'~*VæYaæZAVæYAà*ŽÝ^AX®^^Ýæ*A'àVW3'à*àÝ~AY3ãaYÝYA W | A*à*V′AŁà~*AàŸAŠVÝ~A 8 @ '*a& àÝYAW | A*ŽÝAæ® 8 WÝ^AàŸAYV | ~AxæA*ŽÝA&Ý^3àYÉ

^{ÅY®}ÅŁV′X@′V*ÝYAV~ÅKXXà@æ*~ÅSÝXÝããVW′ÝAMV|~Å&′@~Å0œãÝæ*à^|AMV|~Å′Ý~~ÅKXXà@æ*~ÅQV|VW′ÝAMV|~É

TŽÝA XV~ŽA XàæãÝ^~aàæA X | X ÝAa~A VA æàæEZÝæÝ^V′′ | A VXXÝ&*ÝYA VXXà@æ*aæZA &^aæXa& Ý~A ÅæàæEOKKQBA ŸaæVæXaV′A ä ÝV~@^ÝÉA Ú ÝA WÝ′aÝãÝA*ŽÝA XV~ŽAXàæãÝ^~aàæAX | X ÝAa~A VA@~ÝŸ@´A ä ÝV~@^ÝAæA&^àãaYaæZAaæâÝ~*à^~A ba*ŽAaæŸà^ä V*aàæA^ÝZV^YaæZAà@^AXV~ŽA ä VæVZÝ ä Ýæ*A&Ý^Ÿà^ä VæXÝA VæYA a~A VA baYÝ′ | A VXXÝ&*ÝYA ä ÝV~@^ÝA àŶA bà^âaæZA XV&a*V′A ä VæVZÝ ä Ýæ*A ÝŸaXaYæX |ÉA TŽÝA XV~ŽA XàæãÝ^~aàæA X | X ÝA ~Žà@´YA æà*A WÝA Xàæ~aYÝ^ÝYAæAa~à´V*aàæAà^AV~AVæAV´*Ý^æV*aãÝA*àAà*ŽÝ^AOKKQA ä Ý*^aX~AV~AVæAæYaXV*à^Aà[®]A VA°à^à VæXÝÉ

TŽÝA 'V~*EaæDA Ýa^~*Eà@*A ÁÒÓÑ PBA aæãÝæ*à^|A ä Ý*ŽàYA a~A*ŽÝA &^ÝYà ä aæVæ*A ä Ý*ŽàYA àÝA àŘA à®^*a*A^|A Xà~*aæZA Ýà^A à@^A Ñ'V*ESà'´ÝYA VæYA T@W@'V^A ~ÝZ ä Ýæ*~ÉALV~ÝYAàæA*ŽÝAŁà ä &Væ|`~A'V*Ý~*Aaæ*Ý/æY\ÁŸà^ÝXV~*~AVæYAa*AaæãÝæ*à^|A^Ýå@a^Ý ä Ýæ*~DA ä VæVZÝ ä Ýæ*AYàÝ~Aæà*AWÝ aÝãÝA*ŽÝAÝA ba' 'A¥ÀA*AaæãÝæ*à^|A^Ýå@a^Ý ä Ýæ*~DA ä VæVZÝ ä Ýæ*AYàÝ~Aæà*AWÝ aÝãÝA*ŽÝAÝA ba'@'YAa ä &VX*AÝV^ææZ~AŸà^A*ŽÝA^Ý ä VæYÝ^AàÝAĐÉĐĐÉ

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ŐÝ*AXV~ŽA@~ÝYAæAæãÝ~*æZAVX*aãa*aÝ~A b V~A€GÐA ä a ′′aàæAà^A*ŽÝA*Ž^ÝÝA ä àæ*Ž~AÝæYÝYAØV^XŽA€ÈDAĐËĐĐAXà ä &V^ÝYA*àAæÝ*AXV~ŽA@~ÝYAæA æãÝ~*æZAVX*aãa*aÝ~AàŸA I HÐA ä a ′′aàæAæA*ŽÝA~V ä ÝA&Ý^aà YAæAĐËDÈA&^a ä V^a′ | AY@ÝA*àAXV&a*V′AÝ\&ÝæYa*@^Ý~AÃV~AYa~X@~~ÝYAWÝ′à bBÉ

ŁV&a*V′AÝ\&ÝæYa*@^Ý~Ÿà^A*ŽÝA*Ž^ÝÝA ä àæ*Ž~AÝæYYYAØV^XŽA€ÈDAĐËĐĐDA bÝ^ÝA€FÎA ä a´´aàæDAXà ä &V^ÝYA ba*ŽAÂÈ€HA ä a´´aàæAaæA*ŽÝA~V ä ÝA &Ý^aàYA aæA ĐËĐÈĖAŇ ′V*ESà ´ÝYA XV&a*V′A Ý\&ÝæYa*@^Ý~A bÝ^ÝAÂÈÈIA ä a´´aàæA bŽaXŽA aæX´@YÝ~A ~&ÝæYaæZAŸà^A*ŽÝA Xàæ~*^@X*aàæA àŸA VA &aZA a^àæA ŸVXa′a* | A V*A OV^ | A Ú à^â~DA Žà*A ~*^a&A ä a´´A @&Z^VYÝ~A V*A OV^ | A Ú à^â~DA ä aæaæZA Ýå@a& ä Ýæ*A VæYA à*ŽÝ^A aæŸ/V~*^@X*@^ÝDA ÝæXaàæA àŸA VA &aZA a^à*A ~*^a&A ä a´´A @&Z^VYÝ~A V*A OV^ | A Ú à^â~DA ä aæaæZA Ýå@a& ä Ýæ*A VæYA à*ŽÝA **@X*@^ÝDA ÝæAàæA à¥A VA &aZA a^à*A ŶVXa′a* | A V*A OV^ | A Ú à^â~DA Ža*A ~*^a&A ä a´´A @&Z^VYÝ~A V*A OV^ | A Ú à^â~DA ä aæaæZA Ýå@a& ä Ýæ*A VæYA à*ŽÝA aæŸ/V~*^@X*@^ÝDA ÝæAà ä à ´`A @&Z^VYÝ~A V*A OV^ | A Ú à^â=DA ä aœaæZA Ýå@a& a Ýæ*A VæYA à*ZÝAA aæ ~*^V*ÝZaXA&^àaÝX*~ĖAØaæaAØa´AXV&a*V´AÝ\&ÝæYa*@^Y~Ab ÝAÝAĚÈA ä a´´aàæAVæYAaæX´@YÝYA A&ÝæYaæZAŸà^AXàæ*aæ@à@~AZV´ãVæa{aæZA`æ¥AABAVAYA æàæEZ^VaæAà^aÝæ*ÝYA ´aæÝÉAØaæaAØa´A~YZ ä Ýæ*AXV&a*VÁÝ&Ya*@^Y~AV ~àAaæX´@YÝYAÂÊ€ÍA ä a´´aàæAàŸAXV&a*V´AÝ\&ÝæYa*@^YAAæÝDA *ŽÝA

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Šà ä ÝAàŸA ÞÉAŠÉAŠ*ÝÝ~~AŸVXaʿa*aÝ~A b Ý^ÝAaæAà&Ý^V*aàæAWÝŸà^ÝAÈÎËËÉAK´*Žà@ZŽA*ŽÝAŁà ä &Væ|AWÝ`aÝãÝ~A*ŽV*Aa*~AÝæãa^àæ ä Ýæ*V′A&^VX*aXÝ~A ŽVãÝAÝa*ŽÝ^A ´ÝYA*ŽÝAaæY@~*^|Aà^A V*A ´ÝV~*AWÝÝæAXàæ~a~*Ýæ*A ba*ŽA&^ÝãVaʿaæZAaæY@~*^|A&^VX*aXÝ~DAŽV{VAa@~A ä V*Ý^aV´~AŽVãÝAWÝÝæAVæYA ä V|AXàæ*aæ@ÝA*àAWÝA^Ý´ÝV~ÝYAV*AX@^^Ýæ*Aà^AŸà^ ä Ý^Aà&Ý^V*aæZA~a*Ý~Aà^AYÝ´AãÁ^a*Ý~Aà&Ý^V*ÝAW|A*Ža^YA&V^*aÝ~É

P @^A ÞÉŠÉA ÝVXa 'a*aÝ~A V^ÝA ~@WaÝX*A *àA Ýæãa^àæ ä Ýæ*V′A ′V b ~A V&& 'aXVW'ÝA æA *ŽÝA ÞÉŠÉDA aæX'@YæZA *ŽÝA Ł ´ÝVæA Ka^A KX*A Å*ŽÝA Ł KKBDA *ŽÝA Ł ÝVæA ÚV*Ý^A KX*A ÅŁ ÚKBDA *ŽÝA SÝ~à@^XÝA Ł àæ~Ý^ãV*aàæA VæYA SÝXàãÝ^ | A KX*A ÅSŁ SKBA VæYA *ŽÝA Ł à ä &^ÝŽÝæ~aãÝA Næãa^àæ ä Ýæ*V′A SÝ~&àæ~ÝDA Ł à ä &Ýæ~V*aàæAVæYAÔaVWa 'a* | AKX*AÅŁ NSŁ ÒKBDA V~Ab Ý´´AV~A~*V*ÝAVæYA´àXV′A´V b ~AVæYA^ÝZ@(V*aàæ~É

ÞÉŀÁŠÉŀÁŠ*ÝÝ ′ ľŽV~ŀaæX@^^ÝYAVæYAba´´AXàæ*aæ@ÝA*àAaæX@^H~@W~*Væ*aV′AXV&a*V′DAà&Ý^V*aæZDAVæYA ä Vaæ*ÝæVæXÝAVæYA^Ý ä ÝYaV*aàæAÝ\&ÝæYa*@^Ý~A V~AVA^Ý~@ *A àľAÝæãa^àæ ä Ýæ*V′A ´V b~AVæYA^ÝZ@ ´V*aàæ~DA^Ý `V*ÝYA*àA^Ý ´ÝV~ÝA àľAŽV {V^Yà@~A ä V*Ý^aV´~DA bŽaXŽAaæA^ÝXÝæ*A | ÝV^~AŽVãÝAWÝÝæA ä Vaæ´ | Aľà^A&^àXÝ~~AXŽVæZÝ~A*àA ä ÝÝ*A*ŽÝAŁ KKAàW´aZV*aàæ~AVæYA~a ä a´V^AàW´aZV*aàæ~AaæAN@^à&ÝÉ

EU Environmental Requirements and Slovak Operations

ÞĖÅŠĖÅŠ*ÝÝΊ à &ÝΛV*Ý~ÅV~ÅæàæV**Væä Ť $μ^*$ Å ba²ŽÅ*ŽÝÅĐËÈĐÅVææ@V´ÅQØ_{ĐĖG}Å~*VæYVΛYĖÅ PæÅK&^a´AHDAĐËÈ Í DÅ*ŽÝÅ ÞĖŠĖÅNQKÅ&@W´a~ŽÝYÅVÅæà*aXÝÅ *ŽV*AQÝææ~I ´ãVæ₃VDAŁV´a'Ìà^æ₃VAVæYAÚYVŽàÀ'Va ÝYA*àA~@W ä å*AVAŠ*V*ÝAÚ äᢆ&´Ý ä Ýæ*V*ààæAQ´VæÅÅVæAŠÓQBA*àAYÝ ä àæ~*^V*ÝAV**Vaæ ä Ýæ*A b å*ŽA*ŽÝA ÐËĖÐAŸæÝA&V^*3X@`V*ÝA~*VæYV^YAW|A*ŽÝAYÝVY′æÝAÝ~*VW′a~ŽÝYAW|A*ŽÝAŁKKĖAK~AVA^Ý~@´*AàŸA*ŽÝAæà*3XÝDAQÝææ~|´ãVæ3VDAVA~*V*ÝAaæAbŽ3XŽA bÝλà&Ý^V*ÝDA b V~A^Ý â@z^ÝYA*àA~@W ä z*A VæÅ ŠÓQA*àA*ŽÝA ÞĖŠĖA NQKA æàA ´V*Ý^A*ŽVæAÕàãÝ ä WÝ^A I DAĐËÈ Î A*àA VãàzYA~VæX*aàæ-ĖA PæAK&^a′AĐ Î DA ĐËÈÎDA*ŽÝAK´ÝZŽÝæ|AŁà@æ*|AŒÝV(*ŽAMÝ&V^*äÝæ*AÅKŁŒMBA&@W′a~ŽÝYAVAY^V*AŠÓQAŸà^A*ŽÝAK´ÝZŽÝæ|AŁà@æ*|AæàæV**VæäÝæ*AV^ÝVA bŽaXŽAYÝ ä àæ~*^V*Ý~^4*ŽV*AV´´AàŸAK´´ÝZŽÝæ|AŁà®æ*|Aba´´Aä ÝÝ*Aa*~A^ÝV~àæVW`ÝAŸ@^*ŽÝ^A&^àZ^Ý~~A^Ýå®a^Ý ä Ýæ*~AVæYAWÝAaæAV**Væ ä Ýæ*Aba*ŽA *ŽÝAĐËĖÐAQØ_{₽ŀſA}Vææ@V′AVæYAÐFEŽà@^AÕKKRŠAW | AMÝXÝ ä WÝ^A€ÈDAĐËĐÈDA ba*ŽA*ŽÝAÝ\a~*æZAXàæ*^à´~A*ŽV*AV^ÝAæA&`VXÝĖA ₽æAŠÝ&*Ý ä WÝ^A ÈÐDA ĐËÈÎDA *ŽÝà K΄ÝZŽÝæ|A Łà@æ*|A LàV^YA àŸA ŒÝV *ŽA @æVæa äà@~´|A V&&^àãÝYA *ŽÝA Y^VÝ*A ŠÚŒA TŽÝA Y^VÝ*A ŠÚQA b V~A *ŽÝæA ~Ýæ*A *àA *ŽÝA ŐàāÝ à WÝ^\ÈDAĐËÈ Î ĹATÀAYV*ÝDA*ŽÝA ÞĖŠĹANQKAŽV~Aæà*A*VâÝæAVX*aàæAàæAQKMNQ~~A~@W ä a**VĹA PæAMÝXÝ ä WÝ^AÈ Í DAĐËĐËDA*ŽÝA ÞĹŠĹANQKA &@W'a~ŽÝYA VA ŸæV'A ^@'ÝA &@^~@Væ*A *àA a*~A ~*V*@*à^a' | A ^Ýa@a^ÝYA ^ÝãaÝ bA àŸA ÕKKRŠA *ŽV*A ^Ý*Væ~A *ŽÝA Ý \a~*æZA QØ_{b6}A ~*VæYV^Y~A ba*Žà@*A ^Ýã_{ł~}ačkĺækÝV^ | AĐËĐÈDA~ÝãÝ^V/A~*V*Ý~AVæYAæàæEŻàãÝ^æ ä Ýæ*V′kà^ZVæi{V*aàæ~kľa´ÝYA&Ý*a*aàæ~kľaŶA^ká@YaXaV′k^Ý㥠bÅäᢆĬk*ŽÝAVX*aàæAba*ŽA*ŽÝA TŽÝAXV~ÝA^Ý ä Vaæ~AaæAVWÝ I VæXÝAWÝľà^ÝA*ŽÝAXà@^*A@æ*a′AØV^XŽAÈDAĐËĐĖDAV~AÞÉŠÉANQKAãà @æ*V^a′ I A^ÝXàæ~aYÝ^~A*ŽÝAQØ_{ECC}AÕKKRŠÉAAÓæA Xà@^*ÅڵaʿæZ~DAÞĖŠĖANQKAVYĨa~ÝYA*ŽÝAŁà@^*A*ŽV*Aa*Aaæ*ÝæY~A*àAXà ä&´Ý*ÝAa*~A^ÝXàæ~aYÝ^V*aàæA&^àXÝ~~AW|A&^à&à~aæZAVA^@`ÝAaæAŠ@ä äÝ^A ĐËĐĐA VæYA &^à ä @´ZV*æZA VA^ŶæV′A^@´ÝAæA Š&^æZA ĐËĐ€ĖAA LÝXV@~ÝA ÞĖŠĖA NQKAŽV~A |Ý*A*àAXà ä &´Ý*ÝAa*~A^ÝXàæ~aYÝ^V*aàæA VæYA &^à&à~ÝA VA ^Ýãa~ÝYAQØ_{ĐĖG}AÕKKRŠDAVæ|Aa ä &VX*~AV^ÝAaæÝ~*a ä VW′ÝAV*A*Ža~A*a ä ÝÉ

PæłÔVæ@V^| ADHDAĐËDÈDAKŁŒMAVææà@æXÝYA*ŽV*AŸàvA*ŽÝAŸa~*A*a ä ÝAæAŽa~*à^| AV´AÝaŽ*AVa^Aå@V´a*| A ä àæa*à~Aæ&K´ÝZŽÝæ| AŁà@æ*| A ä Ý*A*ŽÝA ŸÝYÝ^V´AVa^Aå@V´a* | A~*VæYV^Y~AaæX´@YæZDAæA&V^*aX@`V^A~@`Ÿ@^AYaà \aYÝAVæYA&V^*aX@`V*ÝA ä V**ÝAAÂQØ_{DÉG}AVæYAQØ_{ÈE}BĖAQYÝa ä æV^| AYV*VAŸA ä A ĐËDÈAæYaXV*Ý~A*ŽV*AV´´AÝaZŽ*AVa^Aå@V´a* | A ä àæa*à~AXàæ*aæ@ÝA*à\ ä ÝY*A*ŽÝA~*VæYV^Y~ÉAA PæAØV^XŽAÈHDADËDĐDAÞĖŠÉAQYÁ&@W´a~ŽÝYAVAŸa` $^@$ ÝDAVAX´ÝVæAYV*VAYÝ*Ý^ ä æV*aàæDA~Žà bæZA*ŽV*AK´ÝYZŽÝæ | AŁà@æ* | AŽV~AV**VæYYA*ŽÝAĐËÈĐAVææ@V´AQØ_{DÉG}AÕKKRŠAWV~ÝYAàæA*ŽÝAĐËÈ I A [AĐËĐËAV ä WaÝæ*AVa^Aå@V´a* | AYV*VÊALV~ÝYAàæA*ŽÝ~ÝAYV*VDAKŁŒMAa~AæA*ŽÝA&^àXÝ~AàÝA~ÝA`ZYAQKAV&&^àãV`A*àA^YÝYÝ~aZæV*ÝA*ŽÝAV^YA V~AV**Væ ä Ýæ*ADa*ŽA*ŽÝAĐËĖĐAVææ@V´AQØ_{DÉG}AÕKKRŠÉ

Ñà Ả Ý@^*ŽÝ Ả Ya~X@~~aà æł à ÝA Ấ Ýã Væ*A Ýæãa hà æ ä Ýæ*V ʿA ä V**Ý ~ DA aæX´@ YaæZA Ýæãa hàæ ä Ýæ*V ʿA Ấ ä ÝYa V*aàæA à W´aZV*aàæ~DA ~ÝÝA ÆŮ*Ý ä Å ÈÉÅ ÒÝZV ʿA Q^à XÝÝYaæZ~ÉÆ

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ÞÉÅŠÉÅŠ*ÝÝ AYaYAæà*AÝæ*Ý^A&æ*àAVæ | AæÝ b A ä V*Ý^aV / AaŸŸEWV / VæXÝA~ŽÝÝ*AV^^VæZÝ ä Ýæ*~AY@^væZA*ŽÝAľv~*Aå@V^*Ý^AàŸADËĐĐÉ

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ÞÉA ŠÉA Š*ÝÝ A Xàæ*æ@Ý~A *àA ŸVXÝA a ä &à^*A Xà ä &Ýta*aàæDA ä @XŽA àŸA bŽaXŽA a~A @æŸVa^ | A *^VYÝYA VæYA Ÿ@ÝYYA W|A ä V~aāÝA Z'àWV A ~*ÝÝ A àãÝAXV&VXa* |DAX@^Yéz*a ä V*á*a a V*ÝYA*àAWÝA ä ä &à * $2 \times 10^{10} \text{ m}^{10} \text{ m}^{10$

K~AàŸA*ŽÝAYV*ÝAàŸA*Ža~AĬá′æZDA&@^~@Væ*A*àAVA~Ý^áÝ~AàŸAQ^Ý~aYÝæ*aV′AQ^àX′V ä V*aàæ~Aa~~@ÝYAaæAVXXà^YVæXÝAba*ŽAŠÝX*aàæAĐ€ĐAàŸA*ŽÝAT^VYÝA N\&Væ~aàæA KX*A àŸA È Î HĐDA ÞÉŠÉA a ä &à^*~A àŸA XÝ^*VæA ~*ÝÝ′A &^àY@X*~A V^ÝA ~@WáÝX*A *àA VA ĐGA &Ý^XÝæ*a *V^aŸĬDA Ý\XÝ&*ĨA ÄÈBA a ä &à^*~A Ÿ^à ä A K^ZÝæ*aæVDAL^V {a ʿDAVæYAŠà@*ŽAÖà^ÝVDA ĎŽaXŽAV^ÝA~@WáÝX*A*àA^Ý~*^aX*aāÝAå@à*V~ÌAÃĐBAa ä &à^*~AĬ^à ä A*ŽÝAN@^à&ÝVæAÞæaà&AÃNÞBAVæYAÔV&VæA *ŽV*AV^Á ä Ý*ÝYAVæYA&à@^ÝYAaæA*ŽÝANÞÊÔV&VæDA ba*ŽaæAå@V^*ÝA´|A*V^áŸEV/¥Aå@à*VAĨA TSRBA´a ä a*~ÌAÀBAa ä &à^*~AĬ^à ä AŁ VæVYVAVæYAØÝæå A*

PæAÔVæ®V^ | A ĐĐDA ĐËĐÈDA ÕÒØÖA QÝææ~ | ´ãVæaVDA ÒÒŁA VæYA ÕÒØÖA \\ ka a B OÒØÖA \\ ka AÕÒØÖBA \\ a YA VA Łà ä & `Vaæ*A aæA*ŽÝA Łà@**A à\`A Là ä a àæA Q`ÝV~A à\`A K`ÝZŽÝæ | A Łà@æ* | DA QÝææ~ | ´ãVæaVA VZVaæ*A *ŽÝA Łà ä &Væ | ÉA TŽÝA Łà ä & `Vaæ*A v`ÝYA *ŽÝA Łà ä &Væ | A ä VYÝA ä a~YÝ&^Y~àaæ~A*àA*ŽÝAMPŁA^ÝZV^YaæZAÕÒØÖ`~A^Yå@Ý~*~A*àAWÝAY\X´@YÝYA\`A ä & *V^a\`YA & *ŽV*A *ŽYA Łà ä & A*ÝYA & a `Z Þæa*ÝYA Š*V*Ý~A &@^~@Væ*A*àA*ŽÝA @V^XŽA ĐËÈ Í A ŠÝX*aàæA Đ€ĐA Q^Ý~*~A*àAWÝAY\X´@YÝYA ä ä A*V^a\`YA~~Ý~A *ŽV*A *ŽYA Łà ä & A*ÝYA & a `Z Þæa*ÝYA Š*V*Ý~A &@^~@Væ*A*àA*ŽÝA @V^XŽA ĐËÈ Í A ŠÝX*aàæA Đ€ĐA Q^Ý~a¥Y & P^YÝAa ä &à~æZA*V^a\`YA & O`O`ØÖA X`Va ä ~A àã YA ÅÈËËA ä a´`aàæA aæA Xà ä &Yæ~V*à^| A VæYAà*ŽÝ^AYV ä VZÝ~ÉATŽÝA Łà ä & Væ | A^Y ä àãÝYA*ŽÝA X`Va ä A*àA*ŽÝA Þæa*ÝYAŠ*V*YA & A@^*A\`A A`ŽYA Là @^*A\`ÀAAËËËA ä a´`aàæA aæA Xà ä &Yæ~V*à^| A VæYAà*ŽÝ^AYV ä VZÝ~ÉATŽÝA Łà ä & Væ | A^Y ä àãÝYA*ŽÝAX`Va ä A*àA*ŽÝA Þæa*ÝYAŠ*V*Y^AMa~^aX*A Łà@^*A\`ÀA`ŽÝA Là ä & Væ A`AQÝææ~ | ´ãVæaVA àæA ÑÝW^@V^| A ĐGDA ĐËĐÈÉA ÞÉA ŠÉAŠ`ÝY ´A~@W~Ýå@Ýæ*` | A \'a `YA VA Ø`A*ààæA YA A`æAK`ZYA Łà@^*A&a~@ÝYAVæAA&a&AYa~ @ ØV^XŽAĐĐDAĐËĐĐDA*ŽÝAŁà@^*Aa~~@ÝYAVæAà&ææàæAYa~ ä a~~æZAÕÒØÖ`~AXà ä & `Væ*AàæA\`YYY^V V´A&^YY`ä &*aàæAZ^à@æY~AVæYAæàA*a`AY` | AV&&ÝV`A b V~A ä VYÝE

PæAK&^a'AÈÈDAĐËÈ I DA*ŽÝ^ÝA b V~AVA&^àXÝ~~A b V~*ÝEb V*Ý^A/Ý ÝV~ÝAVA*Aà@^AØaYbÝ~*AQ ′Væ*AÃØaYbÝ~*BAæAQà^*VZÝDAÓæYaVæVDA*ŽV*Aa ä &VX*ÝYAVA b V*Ý^A à@*¹V′´A *ŽV*A Ya~XŽV^ZÝ~A *àA L@^æ~A ÚV*Ý^b V | A æÝV^A ÒVâÝA ØaXŽaZVæÉA TŽÝA Łà ä &Væ J A ŽV~A ~ææXÝA a ä & Y ä Ýæ*ÝYA ~@W~*Væ*aV A à&Ý^V*aàæV ƊA &^àXÝ~~A VæYA æà*a^yaXV*aàæAa ä &^àãÝ ä Ýæ*~A V*A ØaYbÝ~*ÉAÓæAÔVæ®V^ | A àYAĐËÈ Í DA TŽÝAŠ@^Ÿ^4YÝ A Ñà@æYV*aàæA VæYA*ŽÝA & ŁŽaXVZàAaæa*aV*ÝYA~@a*~AæA*ŽÝAÕà^*ŽÝ^æAMa~*^aX*AàYAÀġYAÓæYaVæVAV´ÝZaæZAŁÚKAVæYA&Ý^ä a*Aãaà`V*aàæ~AV*AØaYbÝ~*ÉA PæAK&^a'AĐDAĐËÈ Í DA*ŽÝA ÞÉŠÉA NQKA VæYA*ŽÝAŠ*V*ÝA &\AYAØaYaVaVAæYAæYaVAVÝA VA~Ý&V^V*AAZ*aVVYYA

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K~AàŸAØV^XŽA€ÈDAÐËÐÐDAÞÉAŠÉAŠ*ÝÝ'AŽV~A^ÝXÝaãÝYAæÝà^ä V*aàæA^Ýå@Ý~*~Aà^AWÝÝæ4aŸÝAV~AVAQSQAV*AVA*à*V′AàŸAŸà@^AŁNSŁÒKA~a*Ý~DA *Ž^ÝÝAàŸA bŽaXŽAŽVãÝA 'aVWa'a*aÝ~A*ŽV*AŽVãÝAæà*AWÝÝæA^Ý~à ′ãÝYÉALV~ÝYAàæAX@^^Ýæ*′|AVãVa′VW′ÝAæŸà^ä V*aàæDA bŽaXŽAa~AaæA ä Væ|AXV~Ý~A &^Ý′a ä aæV^|AVæYAaæXà ä &´Ý*ÝDA ä VæVZÝ ä Ýæ*AWÝ′aÝãÝ~A*ŽV*A ÞÉAŠÉAŠ*ÝÝ~~A ′aVWa′a*|AŸà^AŁNSŁÒKAX 'ÝVæ@&AVæYA^Ý ä ÝYaV*aàæAXà~*~AV*A*ŽÝA à*ŽÝ^A~a*ÝAba′′AWŹaãÝ~AAĜAā a´⁄aàæAV~AYÝ~X%WÝYAWÝ′àbÉ

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TŽÝAľà^ ä Ý^A ÞÉAŠÉAŠ*ÝÝ AM@ '@*ŽA Ú à^â~A~a*ÝA b V~A& 'VXÝYA àæA*ŽÝAÕV*aàæV 'AQ^aà^a*a'ú × AÒa~*A@æYÝ^A Ł NSŁÒKAæAEÌ Í €AVæYA àæA*ŽÝAŠ*V*ÝA àľA ØææÝ~à*V~AŠ@&Ý^Ÿ@æYA 'a~*A æ&AÈÎ Í FÉA ÒaVWa'a* | A Ýà^A Ýæãa^àæ ä Ýæ*V 'A ^Ý ä ÝYaV*aàæA V*A *ŽÝA ~a*ÝA a~A ZàãÝ^æÝYA W | A VA SÝ~&àæ~ÝA P^YÝAN | A Ł àæ~Ýæ*AÝ \ÝX@*ÝYA ba*ŽA*ŽÝAØQŁKAæAĖÎ Í GAVæYA VASÝXà^YAàŸAMYXa~aàæA~aZæÝYAW | AØQŁKAæAEÌÎ Í ÎÉA ÞÉAŠÉAŠ*ÝY 'AŽV~A&àæ~ÝA P^YÝAN | A Ł àæ~Ýæ*AÝ \ÝX@*ÝYA ba*Ž⁴ZÝAØQŁKAæAEÌÎ Í GAVæYA VASÝXà^YAàŸAMYAàŸAMYXa~aàæA~aZæÝYAW | AØQŁKAæAEÌÎ Í ÎÉA ÞÉAŠÉAŠ*ÝY 'AŽV~A&Àæ~ÝA P^YÝAN | A O^ÝV*AÒVâÝ~AÕV*aàæV 'AQ^àZ^V ä A PĨŶaXÝAÂOÒÕQPBA àŸA*ŽÝA ÞÉŠÉA NQKA SÝZaàæAGA*àA VYY^Ý~AZæ*V ä æW*ÝYA~ÝYa ä Ýæ*A SaãÝ NA ~*@V^ | A VæYA ~Ýã ÝAV'A à&ŽÝA à&ÝAVW 'ÝA @æa*~A *ŽV*A Xà@ 'YA a & ŽYA *ŽYA ÝA *ŽYA * ŽYA *ŽYA * ŽYA Y KZ^ÝÝ ä Ýæ*A WÝ* b ÝÝAA ÉŠÉA Š*ÝY 'A VæYA OÒÕQPA b V~A Ý \Ý X@*¥YA NGV 'A A®YA å@V^*YA & WYA ĎÅDĖÈÍ I A *ÀA ^ÝXÀZæa {ÝA *ŽYA A*ÀA V~aX3V*ÝYA ba*ŽAa & Y´ á Ýæ*aæZA*ŽÝAÝa~*A* bA&ŽV~ÝA Å¥ÝA&A&à&à~ÝYA^Ý a ÝYAV'& X^{*}AÞÉ

SÝ ä ÝY3V*aàæAXàæ*^VX*~Ab Ý^ÝAa~@ÝYAW | AWà*ŽAÞŠŠAVæYAOÒÕQPAŸà^A*ŽÝAŸa~*A&ŽV~ÝAàŸA*ŽÝA^Ý ä ÝY3V′Ab à^âAV*A*ŽÝA~a*ÝAY@^aæZA*ŽÝAŸà@^*ŽA å@V^*Ý^AàŸAĐËĐËËÅÞŠŠAVæYAOÒÕQPAŽVãÝAXàæ*^VX*ÝYAŸà^A*ŽÝA~ÝXàæYA&ŽV~ÝAàŸAb à^âAV*A*ŽÝA~a*ÝAbŽ3XŽAba″AÝ`*ÝæYA*Ž^à@ZŽAÝV^′ | AĐËĐĐÉA TŽÝAŸaæV′A&ŽV~ÝAàŸA*ŽÝA^Ý ä ÝY3V′AYÝ~3ZæAŽV~AWÝÝæAYÝŸaæYYAVæYAVæà*ŽÝ^AV ä ÝæY ä Ýæ*A*àA*ŽÝAQ^àa'ÝX*AKZ^ÝY ä Ýæ*A VæYAOÒÕQPAbV~AÝ\YX@*ÝYAæAMÝXÝ ä WÝ^AĐËĐĚÉAÞŠŠAV&YAVæYAVæYAVæà*ŽÝA~VA ä ÝæY ä Ýæ*A*àA*ŽÝAQ^àa'ÝX*AKZ^ÝY ä Ýæ*A* &ŽV~Ý~AàŸA*ŽYA&^ÝYA*ÝAZÝAAÝ ä ÝY2V′AVÝ a WÝ^AĐËĐĚÉAÞŠŠÅ&à^*àæAàŸAVY2*ààæV'ŨAYÝ~aZæDAàãÝ~aZŽ*AXà~*~DAVæYAaã & Ý ä Ýæ*V*àæAàŸAV′A* &ŽV~Ý~AàŸA*ŽÝA&^ÝYÝ^ŶAYA &ŽV~Ý~AàŸA*ŽÝA&^ÝYA×ÝAAVÝ ä ÝY2V′AV″*Ý^æV*aãÝAàæA*ŽÝA@&′VæYA&Aà&Ý^* | AVæYAN~*@V^ | AV^ÝAX@^^Ýæ*′ | AÝ~*a ä V*ÝYAV~AàŸAØV^XŽA€ÈDAĐËĐĐAV*A V&&^à\a ä V*Ý′ | AÂG€A ä a ″ààæÉ

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PæhPX*àWÝ^hĐĐAÈÎÎÎĹDh*ŽÝhÞĖŠÉhNQKAa~@ÝYhVAŸæWV′hKYäaæa*^^V*aãÝhP^YÝ^hàæhŁàæ~Ýæ*hVYY^Ý~~æZhŁà^ÝX*aãÝhKX*aàæhŸà^hŠà´aYhÚV~*ÝA ØVæVZÝäÝæ*hÞæi*~hÅÝVXŽDhVæhŠÚØÞhVæYDhXà´ÝX*aãÝ[Dh*ŽÝhŠÚØÞ~Bh*Ž^à@ZŽà@*hOV^|AÚà^â~ÉhTŽa~hP^YÝhàæhŁàæ~Ýæ*hYÝå@a^Ý~hÞÉh ŠÉhŠ*ÝÝ'h*àh&Ý^ià^ä a AVæhSŁSKAÑVXa´a* | AĺbæãÝ~*aZV*aàæhÅSŃÓBDAVAŁà^ÝX*aãÝhØÝV~@^Ý~hŠ*@Y|AVæYhŁà^^ÝX*aāÝhØÝV~@^ÝhÓä&Ý á ¥æ*V*aàæÉh NãV′@V*aàæ~AV^Ýh@æYÝ^bV|AVA~a\hZ^à@æYbVÝAhQ^ÝV~hàæh*ŽÝhÝVA*h~aYYhài/h*ŽÝhľVXa´a*|EhKæhĺæ*Ý^aähŠ*VWa`a{V*aàæhØÝV~@^ÝAbà?h&'Væ NãV′@V*aàæ~AV^Ýh@æYÝ^bV|AV*h~a\hZ^à@æYbVÝAhQ^ÝV~hàæh*ŽÝhÝVA*h~aYÝAài/h*ŽÝhľVXa´a*|ÉhKæhĺæ*Ý^aähŠ*VWa`a{V*aàæhØÝV~@^ÝAbà?h&'Væ ŽV~hWÝÝæhV&AaâáÝYhW|h*ŽÝhÞĖŠÉhNQKhŸà^hàæÝhài/h*ŽÝh~a\hV^ÝV~h~aYAVAYaA*^VX*à^hŽV~h^YÝaàa&YV¥a`a&´Ý*ÝAbæ~*V′`V*aàæhVæYha*Íh*ŽÝhA'VA*A ŽV~hWÝÝæhV&AaâáÝYhW|h*ŽÝhÞĖŠÉhNQKhŸà^hàæÝhài/h*ŽÝh~a\hV^ÝV~h&PAVAVAXàæ*^VX*à^hŽV~h^Xýaä'|AXàä&`YYYhba**V'`*aàæhVæYha*Íh*ŽÝha'\hVa*A ŽV~hWÝÝæhV&A^A=|~*ÝäÉhÞæ*a'h*ŽÝhÞĖŠÉhNQKhŸàAàæÝhài/h*ŽÝha'\AVAZYAVAXàæ*^VX*à^hŽV~h^YYhaæ *V′`V*àæhVæYha*IhY* *ŽÝhŶťáYhY`A~|~*Y´äÉhÞæ*a'h*ŽÝhÝť a VæææZhQŽV~ÝhĺbA`ha`AkZYhAQŽV~Ýhĺdh³ha*Y*aàæh&^àáÝX*~hZV*aàæAVVÝhA`aä & 'Ý*ÝYha*hA~hæA*h&àa~a?W'ÝhA`àAV~~Ý~A bŽV*hVY*aāàæVáhV`A`J&ÝhA'Éa VXA@ŶYhA`aäVA`A`hA`K*aàæh&^àáÝX*~h V*hOV^|hÚà^â*à'V`Dh*ŽÝhVXA@ÝYhA`aVVa`a'Na`YhA`a*V Ÿà@^*ŽŁå@V^*Ý^AàŸŁÐËÐËĖŁÞĖŁŠĖŁŠ*ÝÝ′ŁŽV~ŁVæŁVXX^@ÝYŁ′aVWa′a* | ŁàŸŁV&&^à\a ä V*Ý′ | ŁÂÈÎŁ ä a ′′aàæŁV~ŁàŸŁØV^XŽŁ€ÈDŁĐĔĐĐŁŸà^Łà@^ŁÝ~*a ä V*ÝYŁ ~ŽØ^ÝŁàŸŁŽÝŁ^Ý ä VæææZŁXà~*~ŁàŸŁ^Ý ä ÝYzV*aàæŁV*Ł*ŽÝŁ~a*ÝÉ

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bahNÝW^@V^ | ADËDËDAÞĖAŠĖAŠ*ÝÝ A&@^XŽV~ÝYAŽÝAYÝ Z V&AZZAGËA&Ý^XÝæ*Aæ*ÝYÝ ~*AæAÞŠŠEQPŠŁ PAĺæY@~*³Ý ~DAVAľà^ Z ÝAÅààæ*AÄÝæ*@^ÝA*ZV*A a~A 'àXV*ÝYA aæA Qa**~W@^ZDA Ł V'aľà^æaVA WÝ*b ÝÝæA ~@W~aYaVaÝ~A àľA ÞĖA ŠĖA Š*ÝÝ A VæYA QPŠŁ PDA æà bA âæà bæA V~A ÞŠŠEÞQÓDA ÒÒŁĖA Q^aà^A *àA Yà^ Z V*aàæA àľA *ŽÝA jàaæ*A ãÝæ*@^ÝDA ÞQÓÁ~A ľVXa'a*aY~A bÝAÝA & AÝA ÞĖA ŠĖA Š*ÝÝ A VæYA QPŠŁ PDA æà bA âæà bæA V~A ÞŠŠEÞQÓDA ÒÒŁĖA Q^aà^A *àA Yà^ Z V*aàæA àľA *ŽÝA jàaæ*A ãÝæ*@^YDA ÞQÓÁ~A ľVXa'a*aY~A bÝAÝA & AÝA ÞĖA ŠĖA Š*ÝÝ A VæYA à&ÝA V*YÝA ~à Y´I A W | A ÞĖA ŠĖA Š*ÝÝ DA ĎŽaZŽA V~~@ Z ÝYA ^Ý~&àæ~aWa'a* | A Ýà^A *ŽÝA ý\a=*aæZA Ýæãa*àæ ä Ýæ*V'A XàæYa*aæ~ÉA ÞÉA ŠÉA Š*ÝÝ A Xàæ*aæ@Ý~A *àA ä à ææ*à^A* *ŽÝA a ä &VX*~A àľA *ŽÝA AÝ ä ÝYaV'A & VæA a & Y´Y YaæAĐËÈHA*àAVYYAÝ~AZA`@@¥Y A XàæYa*aæ –ÉA ÞÉA ŠÉA Š*ÝÝ A Xàæ*aæ@Ý~A *àA ä àæ*a*A* *ŽÝA a ä &VX*~A àľA *ŽÝA AÝ ä ÝYaV'A & VæA a & Y´Y YaæAĐËÈHA*àAVYYAÝ~~AZA`@@&Y AV*A`A`&&VX*~AľÀà ä A*^aXŽ 'à^à`Y´Z | ÝæYAV*AŠÚ ØÞAFÉANÃV´@V*À *ZÁA àľA *ŽÝA A Y ŽÝA ÝA *ŽYA Á a & YY Y YaæAĐËÈHA*àAVYYAÝA~AZA`@@&DAVæYA*A a ¹/a & AV*A×ÂÝA`& A*AXŽ 'à^à'*Ž | ÝæYAV*AŠÚ ØÞAFÉANÃV´@V*A`& à ¹/a ä&AXÀ *ŽAYÝ Y AzæAĐĚĖHA*àAVYYA /AO^à@&DAVæYA*Aa A'a & A'a & A*A*A*AZ *àAYÝ Y az YAAÀAA YZ *a Z V*AALA & Z *AľàAB Z V*A A'a 'A A'A Z V*AXA *ŽAYÝ Y az YAAÀAAÁY ~*a Z V*AAA * AľàAB ŽVA A YA *A'A *ÀAYÝ Y az YAAÀAAÝA *a Z V*AAAÝA *ZÝA *VA & VAYA A® A^YYAW | A*ŽYAŁ V'aľà^axaVAMÝ &V^* Z Y#AÀAÍATÀ \aXÅŠ@W~*VæXÝ ~AŁàæ*A`A ÉAK *ŽAYÝ XAZVA-AWÝ Y æ&AàA A Z V*AAYA *Z *AľàAB Z VA @AÝAYA *ŽYAÝAŽV ~AWÝ Y æ&AàA A Z V*AAYA Z *Z *A *ZÝA *V*@ ~AàÝA *A A A A**@ZXA@**ZA YZA *Z YA YA Z YA YA X Z *EDA ĐĚĐĐDA V&&A`A Z X *Y Y A XÀ * *AľÀAA Z VA A ŴÝ A A **2@ZXA®**ZA Y XAYA YA V A X Z *AÝYA Z A XA XA *Z *AÝA Z *A ŠaZæAľAXVæ*AVYY a ×AVYYA A Z *AV~A A Z *Z *ÁXA A*ÝA ×ZYA × VYA NæV XAVÁ X *VYYA ŽA *A VA A *ZYA A XA * A[†]A A XZ *Z *Z VA YÝA ŽX *AVYYA *AZ * AL YA XA * A[†]A A A[†]Y XA *Z VA YÝA Z *A VYYA Z XA * AV~A NæV XAVAÝ XÝA XA * *A/VA A XA * A *Z VA *®YA YYA Z *A L Àæ*ZAXA *A AV A A ŽYA ×A Z *A YYA YA XA *Z

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ÚæAPX*àWÝ^AÐËÈGDAO^Væa*ÝAŁa* | A Ú à^â~A^ÝXÝaãÝYAVAUaà 'V*aàæAÕà*aXÝA^I/à ä A*ŽÝAÓ´íæàa~ANæãa^àæ ä Ýæ*V′AQ^à*ÝX*aàæAKZÝæX | AÅ*ŽÝAÓNQKBAœA bŽaXŽA*ŽÝAÓNQKAV´ÝZÝ~A*ŽV*A ÞÉAŠÉAŠ*ÝÝ 'A ãaà 'V*ÝYA*ŽÝAÝ ä a~~aàæA 'a ä a*~AŸà^Aæa*^àZÝæAà \aYÝ~AÅÕP \BAVæYA ãà 'V*a YAà^ZVæaXAXà ä &à@æY~A Ý^à ä A*ŽÝA LV~aXA P \ | ZÝæAÑ®^æVXÝA N ÝX*àa~*V*aXA Q^ÝXa&a*V*à^A Š*VXâÉAÓæA VYYa*aàæDA *ŽÝAÓNQKA V´ÝZÝ~A *ŽV*A ÞÉAŠÉAŠ*ÝÝ 'A Ý \XÝÝYA*À æV*®^V′AZV~A®~VZÝA 'a ä a*AV*Aa*~AŁàOÝæÝ^V*aàæALàa Ý⁄ÉA ÞÉAŠÉAŠ*ÝÝ 'A^Ý~&àæYÝYA*àA*ŽÝAæà*aXÝAVæYAa~AX®^Ýæ*´ | AYa~X®~~aæZA^Ý~à '@*aàæA&ŸA *ŽÝA ä V**Ý^A ba*ŽAÓNQKÉ

K*Žà@ZŽA Ya~X@~~aàæ~A ba*ŽAÓNQKA ^ÝZV^YaæZA *ŽÝA Ÿà^ÝZàaæZA V´´ÝZÝYA ãaà `V*aàæ~A V^ÝA àæZàaæZA VæYA *ŽÝA ^Ý~à`@*aàæA àŸA *ŽÝ~ÝA ä V**Ý^~Aa~A @æXÝ^*VaæAV*A*Ža~A*a ä ÝDAa*Aa~Aæà*AVæ*aXa&V*ÝYA*ŽV*A*ŽÝA^Ý~@ *AàŸA*Žà~ÝAYa~X@~~aàæ~A ba´´AWÝA ä V*Ý^aV´A*AAÞÉAŠÉAŠ*ÝÝ´É

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₽æ٨ ÑÝW^@V^1A HDA ĐËÈ€DA *ŽÝA ÞĖŠĖA NQKA &@W′a~ŽÝYA VæA ÑÓQA *ŽV*A V&&´aÝ~A *ÀA *VXàæ*ÝA ŸVXa′a*aY^~A aæA ØaææÝ~à *VĖA KæA ÑÓQA Ý~*VW′a~ŽÝ~A VæYA ^Ýå@&^^A Ýä&~~&àæ& ´aäa*~& VæYA *ŽÝA @~ÝA àŸA ´àbA ÕP\A ^ÝY@X*&àæA *ÝXŽæà´àZ|A àæA &&Y@^V*&æZA Ý@^&VXÝ~A V~A LÝ~*A KÃV&′VW´ÝA SÝ*^àŸa*A ŦÝXŽæàʿàZ |Ėħ ÚŽ₄Ýħ ÞĖħŠĖħŠ*ÝÝ′ħæ+*V´ÝYħ′à bħÕ₽ \ħ₩@^æÝ^~ħàæħ*Ž^ÝÝħŸ@^æVXÝ~ħV*ħØææ*VXħVæYħa~ħX@^^Ýæ*´|ħà₩ĩaZV*ÝYħ*àħæ~*V´'n (à bħ ÕP\8W@^æÝ^~&àæ&*ŽÝ&*bà&à*ŽÝ^&Ÿ@^æVXÝ~&V*&Ø*##XX&&@^~@V#*&*à&Ý\8~**#Z&VZ^ÝY ä Ý#*~&V#Y&&Ý^ ä *~D&*ŽÝ&^@´Y&bà@`Y&^Y*ŽÝ& aæ~*V´′V*aàækàŸkVk´à ÞkÕ₽ \kW@^æÝ^kàæk*ŽÝkàæÝkŸ@^æVXÝkV*kÖÝÝ*VXkŸà^kbŽaXŽkÞÉkŠÉvŠ*ÝÝ´kYaYkæà*kŽVãÝkVækà*ŽÝ^ba~ÝkÝ\a~*æZkàW′aZV*aàæÉk ÞÉÁŠÉÁŠ*ÝÝ′ÁÝ~*a ä V*Ý~AÝ \ &ÝæYa*@^Ý~AV~~àXaV*ÝYA ba*Ž4*ŽÝAzæ~*V′′V*aàæAàŸA′à b AÕP \AW@^æÝ^~AàŸAV~A ä @XŽAV~AÂÐGA ä a ′′aàæA*àA€ËA ä a ′′aàæÉA ŇŮQAVæYAYÝæ3V′AÀ^ŸA*ŽÝAØ3ææÝ~à*VAŠŮQA*àA*ŽÝAN3ZŽ*ŽAŁ3^X®3*ĚAŮæ4K&^3′AĐËÈHDA*ŽÝAÞĖŠĖANQKA&^à ä @´ZV*ÝYAVA^Ýãa~ÝYAŇŮQAÞ3*ŽÝA~V ä ÝA ~@W~*Væ*aãÝA^Ýå@a^Ý ä Ýæ*~AŸà^A ÞÉAŠÉAŠ*ÝÝ ÉAÔ@&ÝAĐËÈHDA ÞÉAŠÉAŠ*ÝÝ AŸa ÝAVA&Ý*a*aàæAŸà^AVV ä aæa~*^V*aãÝA^ÝXàæ~aYÝ^V*aàæAàŸA*ŽÝAĐËÈHA <u>&</u>^àXÝÝY≀æZ~&^ÝZV^Y≀æZA*ŽÝ&&Ý*a*aàæÅŸà^Ai@Y≀X3V′&^ÝãiÝ b ÀàŸå*ŽÝ&ĐËÈ€ÅÑÓQ&^Ý ä V≀æÝYA~*V | ÝYD&à^V′&V^Z@ ä Ýæ*~&^ÝZV^Y≀æZA*ŽÝ&&Ý*a*aàæÅŸà^A á@YaXaV′A ^ÝãaÝÞA ^Ý Ä VæA Þa*ŽA *ŽÝA NaZŽ*ŽA Ła^X@a*ÉA PæA MÝXÝ Ä WÝ^A FDA ĐËÈ I DA *ŽÝA ÞĖŠĖA NQKA &@W′a~ŽÝYA VA æà*aʲaXV*aàæA aæA *ŽÝA ÑÝYÝ^V′A SÝZ₂~Ý^Aæ&A ĎŽaXŽA*ŽÝA ÞĖŠĖA NQKA YÝæ3ÝYA ÞĖA ŠĖA Š*ÝÝ~~A VY ä aæa~*^V*aã ÝA &Ý*a*ààæ~AŸÀ^ÝXÀæ~aYÝ^V*aàæA VæYA ~*V |A àŸA*ŽÝAĐËÈ€AÑÓQA VæYA *ŽÝAľaãÝAaæY@^V*aæZA′aæÝ~AV*AØaææ*VXĖAKĽ*ÝYA&A^à&à~aæZAVA^Ýãa~ÝYAÑÔQAVæYA^Ý~&àæYæZA*àA&@W′aXAXàäääÝæ*~DAàæAØV^XŽAÐDAĐËĐÈDA*ŽÝA

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₽æ٨MÝXÝ ä WÝ^٨ÐFDAÐËÈ Í DAÞÉAŠÉAŠ*ÝÝ ¼~AŁ ′Va^*àæAQ′Væ*AÝ \&Ý^&ÝæXÝYAVAľa^ÝDAVĨÝaY*aæZA&à^*aàæ~AàÝA*ŽÝAĬVXa´a* | Aaæãà´ãÝYAaæAYÝ~@´Ŷ@^a{V*aàæA àŸѦ*ŽÝѦӼàâÝæłZV~łZÝæÝ^V*ÝYѦY@^┉Z⅄*ŽÝѦӼàâ┉Z⅄&^àXÝ~~ĖѦÚォ*ŽŕᢥYÝ~@´Ÿ@^ኔ{V*iàæł&^àXÝ~~łà@*łàŸłà&Ý^V*₃àæłV~ŁVŁ^Ý~@´*łàŸł*ŽÝѦ Ŷġ^ÝDĂ ÞÉĂ ŠĖĂ Š*ÝÝ ¼ b V~Ăæà*Ă VW ÝĂ*ÀĂ XÝ^*aŸ | Ă XÀ ä & ʿaVæXÝĂ ba*ŽĂ Ł ´Vź^*àæAQ´Væ*´~ĂTā*´ÝĂ UĂ &Ý^ ä a*A ÝãÝ´~Ă ŸÀ^A~@ Ŷ@^A Ý ä a~~aàæ~ÉĂ ÞÉĂ ŠĚĂ Š*ÝÝ´Ă &^à ä &*´ | Aæà*ðáÝYAKŁŒMDA bŽ3XŽAŽV~A^ÝZ@´V*à^ | A \$@^3~Y3X*ààæA ¥à^A*ŽÝAT&*´ÝA UA &Ý^ ä &*DA VæYA @&YV*ÝYA*ŽÝAKŁŒMA^ÝZ@´V^´ | A àæAÝŸYÀ^~A*àA ä a*aZV*ÝA Væ|A &à*Ýæ*aV′A Ýæãa^àæä Ýæ*V′A a ä &VX*~A @æ*a′A *ŽÝA YÝ~@´Ý@^a{V*aàæA &^àXÝ~~A bV~A ^Ý*@^æÝYA *àA æà^ä V′A à&Ý^V*aàæ-ÉA PÝA *ŽÝA V&&^à\a ä V*Ý´ | AĐDFËËAŽà@^~AWÝ* bÝÝæA*ŽÝA YV*ÝA àľA*ŽÝA ½^ÝA VæYAK&^½A FDAĐËÈÎDA bŽÝæA*ŽÝA Łà ä &Væ | A^Ý~@ ä ÝYA YÝ~@ 1 @^½ {V*ààæDA*ŽÝAÝA bÝvÝA*ÝæAæ*Ý^ä a**Ýæ*AŽà@^~AbŽÝvÝAVãÝ^VZÝAŠP_bAÝ ä a~~aàæ~AÝ\XÝÝYÝA*ŽÝAŽà@^´|AŐKKRŠAŸà^AŠP_bA\Y*A*ŽÝAK´´ÝZŽÝæ|AŁà@æ*|A^ÝZåàæV/A Va°Nå@V´a* | A ä àæa*à^~A´àXV*ÝYAaæAÖaWÝ^* | AVæYAÕà^*ŽAL^VYYÀXâAWà^à@ZŽ~DAbŽaXŽAV^ÝA&ÝV^AÞÉAŠÉAŠ*ÝÝ´Á~AØàæAUV´´Ý | A Ú à^â~A^IVXa´a*aÝ~XAAWà^à@ZŽ~DAbŽaXŽAV^ÝA&ÝV~AÞÉAŠÉAŠ*ÝÝ´Á~AØàæAUV´´Ý | A Ú à^â~A^IVXa´a*aÝ~ZA ÑÝW^@V^|À È€DA ĐËÈÎDA QÝææNæãa⁄àæäÝæ*A VæYA ŁÝVæA Ka⁄A Łà@æXa′DA Wà*ŽA Ýæãa⁄àæäÝæ*V′DA æàæEZàãÝ⁄æäÁ∕æäÁ⁄2Væa{V*aàæ~DA ~Ýæ*A ÞĖÅŠĖÅŠ^vÝÝ (AVAHËEYV | Aæð*3XÝAð⁽Aaæ*Ýæ*A*àA~@ÝA 'Ý**Ý^A&@^~@Væ*A*àA*ŽÝAŁ KKĖATŽÝA'Ý**Ý^AV ´ÝZÝYAT3*´ÝAUA&Ý^ä a*Aãaà 'V*aàæ~AV*Å*ŽÝAŁ 'Va^*àæDA ĺvājæDAVæYANYZVvATŽà ä ~àæAľVXjja*jÝ~AV~AVAvÝ~@ *AàľA*ŽÝAMÝXÝ ä WÝvAÐFDAÐËÈÍAŁ ´Vav*àæAQ´Væ*AľavÝÉATŽÝAHËEYV | Aæà*aXÝA´Ý**ÝvAV´~àAV´ÝZÝYA *ŽV*A*ŽÝANà Ÿ A ‱‰ ‰‰ à^ZVæ 1 à^æäQ (

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jurisdiction, then such provisions shall be deemed reformed in such jurisdiction juri

security), and shall also be entitled to require Breves to account for and pay over to the Company all compensation, profits, moneys, accruals, increments or other benefits derived from or received as a result of any transactions constituting a breach of the covenants contained herein, and shall also be entitled to cease paying or providing and be entitled to require Breves to repay all amounts paid pursuant to **paragraph 2 (Consideration)** only of this Agreement. In addition, in the event of an alleged breach or violation by Breves of paragraph 7 (Non-Competition

14. MODIFICATION. The provisions of this Agreement may not be modified by any subsequent

Agreement as originally executed unless otherwise specified. Any reference herein to any statu

Attachment A

- (f) She may revoke this General Release at any time within **seven (7) calendar days** of the General Release Execution Date by delivering a written notice of revocation to the Company's General Counsel;
- (g) If she does not exe

participating in the Plan, the Participant shall be deemed irrevocably to have agreed not to pursue such claim and agreed to execute any and all documents necessary to request dismissal or withdrawal of such claim; aws in connection with the

(k) it

- (x) it aws in connection with the issuance and delivery of Shares pursuant to the vesting of the Performance Share Award;
 (1) the Corporation and the Employing Company are not providing any tax, legal or financial advice, nor are the Corporation or the Employing Company making any recommendations regarding the Part

16. <u>Severability</u>: In the event that any provision in this Agreement is held invalid or unenforceable, such provision will be severable from, and such invalidity or unenforceability will not be construed to have any effect on, the remaining provisions of this Agreement.

17. Language: If the Participant has received this Agreement or any other document related to the Plan translated into a language other than English and if the meaning of the translated version is different than the English version, the English version will control.

18. <u>Governing Law and Venue</u>: This Agreement shall be construed and enforced in accordance with the laws of the Commonwealth of Pennsylvania, without regard to the conflicts of laws thereof

EXHIBIT A

Performance Goals for the Performance Period

Threshold

EXHIBIT B

Confidentiality and Proprietary Rights Agreement

Agreement

Exhibit B to, and incorporated as a part of, the United States Steel

Corporation Performance Share

2. <u>Protection of Proprietary Rights</u>.

(a) **Work Product**. The Employee acknowledges and agrees that all writings, works of authorship, technology, inventions, discoveries, ideas and other work product of any nature whatsoever, that are created, prepared, produced, authored, edited, amended, conceived, or reduced to practice by the Employee, individually or jointly with others, during the period of the elating in any way to the business or contemplated business, research, or development of the Employer and all printed, physical, and electronic copies, all improvements, rights, and claims related to the foregoing, and other tangible embodiments thereof (collectively, "**Work Product**"), as well as any and all rights in and to copyrights, trade secrets, trademarks (and related goodwill), patents, and other intellectual property rights therein arising in any jurisdiction throughout the world and all related rig

8. Successors and Assigns.

(a) The Employer may assign this Agreement to any subsidiary or corporate affiliate, or to any successor or assign (whether direct or indirect, by purchase, merger, consolidation, or otherwise) to all or substantially all the business or assets of the Employer. This Agreement shall inure to the benefit of the Employer and permitted successors and assigns.

(b) No Assignment by the Employee. The Employee may not assign this Agreement or any part hereof. Any purported assignment by the Employee shall be null and void from the initial date of purported assignment.

9. <u>Governing Law</u>. This Agreement, for all purposes, shall be construed in accordance with the laws of Pennsylvania without regard to conflictsof-law principles.

10. <u>Entire Agreement</u>. Unless specifically provided herein, this Agreement contains all the understandings and representations between the Employee and the Employer pertaining to the subject matter hereof and supersedes all prior and contemporaneous understandings, agreements, representations, and warranties, both written and oral, with respect to such subject matter.

11. <u>Modification and Waiver</u>. No provision of this Agreement may be amended or modified unless such amendment or modification is agreed to in writing and signed by the Employee and by a duly authorized officer of the Employer (other than the Employee). No waiver by either of the Parties of any breach by the other party hereto of any condition or provision of this Agreement to be performed by the other party hereto shall be deemed a waiver of any similar or dissimilar provision or condition at the same or any prior or subsequent time, nor shall the failure of or delay by either of the (Em)16(p)-6(1)9(o)7(y)-6(e)-87 7(y)-

EXHIBIT C

Non-Competition Agreement

This Non-Agreement
Grant Agreementtached as Exhibit C to, and incorporated as a part of, the United States Steel Corporation Performance
is applicable to the Participant named in the Grant Agreement to the extent provided in Section11 of the Grant Agreement.For purposes of this
is applicable to the States Steel Corporation and its subsidiaries or affiliates are described as the
in the Grant Agreement.Employee
meI , and the Employer and theEmployee are collectively referred to herein as the
Employee are collectively referred to herein as the
Image: Steel Corporation PerformanceEmployee
meI , and the Employer and the

1. Definitions.

- (a) rvices sold by the Company, or any prospective product or service the Company took steps to develop for which I had any responsibility during the 24 months preceding the termination of my employment.
- (b) ry (i) within sixty miles of the area in which I worked or (ii) over which I had responsibility or (iii) that the nature and scope of my duties could have affected, during the 24 months preceding the termination of my employment, whichever is greatest. Restricted territory may be national or global depending on the nature of my duties and the knowledge acquired in the performance of those duties.
- 2. <u>Non-Competition</u>. During my employment and for 12 months after termination of my employment for any reason, I will not directly or indirectly, on behalf of myself or in conjunction with any other person or entity:
 - (a) own any business (other than less than 5% ownership in a publicly traded company) that sells Competing Products in the Restricted Territory; or
 - (b) work in the Restricted Territory for any person or entity that sells Competing Products, in any role.
- 3. Non-Solicitation of Customers & Employees 1 0 0 1 252.65 542.26 Tm0 G[)]TJET@MC /P &MCID 11&DC q1 0 0 1 245.569.86 Tm12()-182(o)-6(w)21(n)-6(

9. <u>Injunctive Relief and Attorney's Fees</u>. Employee agrees that in the event Employee breaches this Agreement, the Company will be irreparably harmed and entitled to an injunction

EXHIBIT D

Additional Terms and Conditions of the United States Steel Corporation 2016 Omnibus Incentive Compensation Plan Performance Share Award Grant Agreement

TERMS AND CONDITIONS

This Exhibit D includes additional terms and conditions that govern the Performance Share Award granted to the Participant under the Plan if he or she works or resides in one of the countries listed below. If the Participant is a citizen or resident of a country other than that in which the Participant is currently working or transfers employment to another country after the Performance Share Award is granted, the Corporation shall, in its discretion,

advisor. The Corporation cannot be held liable if the Participant violates the UK's insider dealing rules. The Participant is responsible for ensuring his or her compliance with these rules.

UNITED KINGDOM, EUROPEAN UNION AND EUROPEAN ECONOMIC AREA

For Participants who reside in the United Kingdom, European Union or the European Economic Area, the following provisions replace the Data Privacy provisions in Section 14 of the Agreement.

(a) **Data Collected and Purposes of Collection**. The Participant understands that the Corporation, acting as controller, as well as the Employing Company, may collect, to the extent permissible under applicable law, certain personal information about the Participant, including name, home address and telephone number, information necessary to process the Performance Share Awards (e.g., mailing address for a check payment or bank account wire transfer information), date of birth, social insurance number or other identification number, salary, nationality, job title, employment location, any Shares or directorships held in the Corporation (but only where needed for legal or tax compliance), any other information necessary to process mandatory tax withholding and reporting, details of all Performance Share Awards granted, canceled, vested, unvested or out applicable service termination date and reason for termination **Data** The Data is collected from the

applicable service termination date and reason for termination Data The Data is collected from the Participant, any Employing Company and the Corporation, for the exclusive purpose of implementing, administering and managing the Plan pursuant to the terms of this Agreement. The legal basis (that is, the legal justification) for processing the Data is to perform this Agreement. The Data must be provided in order for the Participant to participate in the Plan and for the participate to this Agreement to perform their respective obligations thereunder. If the Participant does not provide Data, he or she will not be able to participate in the Plan and become a party to this Agreement.

(b) **Transfers and Retention of Data**. The Participant acknowledges and understands that the Employing Company will transfer Data to the Corporation for purposes of plan administration. The Employing Company and the Corporation may also

providers (such as accounting firms, payroll processing firms or tax firms), as may be selected by the Corporation in the future, to assist the Corporation with the implementation, administration and management of this Agreement. The Participant understands that the recipients of the Data may be located in the United States, a country that does not benefit from an adequacy decision issued by the European Commission and is not listed by the Swiss supervisory authority as a country with adequate data protection legislation. Where a recipient is located in a country that does not benefit from an adequacy decision or adequacy listing, the transfer of the Data to that recipient will be made pursuant to European Commission-approved standard contractual clauses when required by applicable law, a copy of which may be obtained by contacting

United States Steel Corporation 2016 Omnibus Incentive Compensation Plan Performance Share Award Grant Agreement

United States Steel Corporation, a Delaware c id

Name of Participant:

PARTICIPANT NAME

TSR Performance Award - February 2022

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relevant taxable event, the Participant acknowledges that the Corporation and/or the Employing Company (or former Employing Company, as applicable) may be required to withhold or account for Tax-Related Items in more than one jurisdiction.

Prior to the relevant taxable event, the Participant shall pay or make adequate arrangements satisfactory to the Corporation and/or the Employing Company to satisfy all Tax-Related Items of the Corporation and/or the Employing Company. In this regard, the Participant shall pay any Tax-Related Items

- the Corporation and the Employing Company are not providing any tax, legal or financial advice, nor are the Corporation or the Employing sale of the Shares underlying the Performance Share Award;
- (m) the Participant is hereby advised to consult with his or her own personal tax, legal and financial advisors regarding his or her participation in the Plan before taking any action related to the Plan;
- (n) unless otherwise provided in the Plan or by the Corporation in its discretion, the Performance Share Award and the benefits evidenced by this Agreement do not create any entitlement to have the Performance Share Award or any such benefits transferred to, or assumed by, another company nor to be exchanged, cashed out or substituted for, in connection with any corporate transaction affecting the Shares of the Corporation; and
- (o) the following provisions apply only if the Participant is providing services outside the United States:
 - (i) the Performance Share Award and Shares underlying the Performance Share Award are not part of normal or expected compensation for any purpose; and
 - (ii) the Participant acknowledges and agrees that neither the Corporation nor the Employing Company shall be liable for any foreign exchange rate fluctuation between the local currency and the United States Dollar that may affect the value of the Performance Share Award or 8of any amounts due to the Participant pursuant to the settlement of the Performance Share Award or the subsequent sale of any Shares acquired upon settlement.

13. Data Privacy:

(a) The Participant hereby explicitly, unambiguously and voluntarily consents to the collection, use, disclosure and transfer, in electronic or other form, of his or her personal data as described in this Agreement and any other Performance Data applicable, any Employing Company and the Corporation for the exclusive purpose of implementing, administering, and managing his or her participation in the Plan.

(b) The Participant understands that any Employing Company and the Corporation may collect, maintain, process and disclose certain personal information about him or her, including, but not limited to, his or her name, home address and telephone number, date of birth, social insurance number or other id

EXHIBIT A

Performance Goals for the Performance Period

		Threshold	Target	Maximum	
Performance Goal	U. S. Steel's TSR Performance Relative to				

- (b) If a Peer Group Company is acquired by another company or entity, including through a management buy-out or going-private transaction, the acquired Peer Group Company will be removed from the Peer Group for the Performance Period; provided that if the acquired company became bankrupt prior to its acquisition it shall be treated as provided in paragraph (a), above, or if it shall become delisted according to paragraph (e), below, prior to its acquisition it shall be treated as provided in paragraph (e).
- (c) If a Peer Group Company sells, spins-

EXHIBIT B

Additional Terms and Conditions of the United States Steel Corporation 2016 Omnibus Incentive Compensation Plan Performance Share Award Grant Agreement

TERMS AND CONDITIONS

This Exhibit B includes additional terms and conditions that govern the Performance Share Award granted to the Participant under the Plan if he or she works or resides in one of the countries listed below. If the Participant is a citizen or resident of a country other than that in which the Participant is currently working or transfers employment to another country after the Performance Share Award is granted, the Corporation shall, in its discretion, determine to what extent the terms and conditions contained herein shall be applicable to the Participant. Certain capitalized terms used but not defined in this Exhibit B have the meanings set forth in the Plan and/or the Agreement.

NOTIFICATIONS

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ÍÂA FOVPÔAĐÀAĐÙÚÚPŨŨÂAÓÖÚŨPÒYAŨÕOÜÊ

BÅ ÍAŐOVÖAÚÖVPÖWÖÔAŬÕPÛAUÙOÚÜÖÚRYAÚÖÞTÚŨATŠAHTÚ SABÃÅ JATÒAMŠPÜÖÔA LÜOÜÖÛA LÜÖÖRA€TÚÞTÚOÙPTŠĖ

CÀ

ÍÂA€ÕÚPÛÜPŠÖAŁÀAÐÚÖVÖÛÂAÓÖÚŰPÒYAŰÕOŰÊ

- BÀ ÍAŐOVÖAÚÖVPÖWÖÔAŰŐPÛAUÙOÚŰÖÚRYAÚÖÞTÚŰATŠAHTÚSABÃÄKATÒANŠPŰÖÔAŁŰOŰÖÛAŁŰÖÖRA€TÚÞTÚOŰPTŠĔ
- CẢ ĐOÙÔÔATŠA S YAQŠTWRÔÔØÖÅAŮÕPŮAŮŎÞTÚŬAÔTÖÛAŠTÜAÓTŠŮOŘŠAOŠYAÙŠŮŮŮÖAŮŮOŬŎ S ÖŠŬATÒAOA S OŮŎÚPORAÒOÓŬATÚAT S PŮAŬTAŮŮOŬŎAOA S OŬŎÚPORA ÒOÓŨA ŠŎÓÔŮÛOÚYAŮTA S OQÖAŮÕŎA ŮŮOŬŎ S ÖŠŮÛA S OÔŎÂA PŠARPØÕŬA TÒAŮÕŎAÓPÚÓÙ S ÛŬOŠÓÖÚA ÙŠÔÖÚA WÕPÓÕA ÛÙÓÕA ÛŮOŬŎ S ÖŠŮÛA WÖÚŎA S OÔÖÂA ŠTŮA S PŮRÕOÔPŠØAWPŨÕAŮÕÛÞÖÓUAŮTAŬÕŎAĐŎÚPTÔAÓTVŎÚÖÔAŒYAŬÕPŮAŮÕÞTÚŮĔ
- ÇÅ ĐOÛÖÔATŠA S YAQŠTWRÖÔØÖÅAÚÕÖAÓPŠOŠÓPORAÛŬOŬÖ S ÖŠÜÛÅAOŠÔATÜÕÖÚAÓPŠOŠÓPORAČŠÓTÚ S OŬPTŠAPŠÓRÙÔÖÔAPŠAÚÕPÚAÚÖÞTÚÚÅAÒOPÚRYAÞÚÖÛÖÖŠÚAPŠA ORRA S OÜÖÚPORA ÚÖÜÞÖÓUÛA UÕÖA ÓPŠOŠÓPORA ÓTŠÔPŮPTŠÅA ÚÖÛÙRUÛA TÒA TÞÖÚOŮPTŠÛA OŠÔA ÓOÛÕA ÓRTWÛA TÒA UÕÖA ÚÖØPÛÜÚOŠŬA OÛA TÒÅA OŠÔA ÒTÚÁA UÕÖA ÞÖÚPTÔÛAÞÚÖÛÖŠÜÖÔAPŠAŬÕPÚAÚÔÞTÚĽE
- DÀ MÕÖA ÚÖØPÛUÚOŠUÝÛA TÜÕÖÚA ÓÖÚUPŮYŠØA TÙ/PÓÖÚA OŠÔA ÍA OÚÖA ÚÖÜÞTŠÚPŒRÖA ŮTÚA ÖÛUOŒPÛŨPŠØA OŠÔA S OPŠUOPŠPŠØA ÔPÛÓRTÛÙÚÖA ÓTŠUÚTRÛA OŠÔA ÞÚTÓÖÔÙÚÖÛAEOÛAÔÖ/PŠÖÔAPŠAGXÓÕOŠØÖAÈÓÜA L ÙRÖÛABÇOÄBEEÖÁAOŠÔABEÔÄBEEÖÁAOŠÔABEÔÄBERÖÁÁOŠÔAPŠÜÖÚŠORAÓTŠUÚTRATVÖÚA/PŠOŠÓPORAÚÖÞTÚÚPŠØAEOÛA ÔÖ/PŠÖÔAPŠAGXÓÕOŠØÖAÈÓÜA L ÙRÖÛABÇOÄBEE/ÁAOŠÔABEÔÄBEE/ÖÁABE/ÖÁBEE/ÖÁAOŠÔABEÔÄBOÚÚÓOVÓÉ
 - OÁA FÖÚPØŠÖŐA ÚÙÓŐA ÓPÚÓRTÚÙÚÖA ÓT ŠIÚTRÚA OŠÔA ÞÚTÓÖÔÙÚÖÚÁATÚA ÓOÙÚŐÓA ÓPÚÓRTÚÙÚÖA ÓT ŠIÚTRÚA OŠÔA ÞÚTÓÖÔÙÚÖÚAUTA ŒÖA ÔÖÚPØŠÖŐA ÙŠÔÔÚA TÙÚA ÛÙ ÞÖÚVPÚPTŠÁA ÚTA ÖŠÚÙÚÖA ÚÕOÙA SOŬÓÚPORA PŠŮTÚ SOÚPTŠA ÚÖROÚPŠØA ÚTA ÚŐÖA ÚÖØPÛÚÚOŠÚÁA PŠÓRÙÔPŠØA PŮÚA ÓTŠÚTRPÔOŬÖÔA ÛÙ ŒÛPÔPOÚPÖÚÁAPÚA SOÔÖAQŠTWŠAÚTA ÙÚA ŒYA TŪÕÖÚÚA WPŮÕPŠA ŮÕTÚÖA ÖŠÜPÜPÖÚÁA ÞOÚPÓÙROÚRYAÔÙÚPŠØA ŰÖ WÕPÓŐA ĽŐPÚA LÚČOPŠØA ÞÚÖÞOÚÓÔÉ
 - ŒÁA FÖÜPØŠÖÖALÜLÓÖAPŠUÖUŠORAÓTŠUÚTRATVÖÚAÚPŠOŠÓPORALÚÖÞTÚPŠØÁATÚAÓOLÜÖÖALÜLÓÖAPŠUÖUŠORAÓTŠUÚTRATVÖÚAÚPŠOŠÓPORALÚÖÞTÚPŠØA ÚTA ŒÖA ÔÖÚPØŠÖÔA ÙŠÔÖÚA TÙÚA ÛĽÞÖÚVPÚPTŠÁA ÚTA ÞÚTVPÔÖA ÚÖOÚTŠOŒRÖA OÛÛÙÚOŠÓÖA ÚÖØOÚÔPŠØA ÚÖÖR ÚÖRPOŒRPÚYA TÒA ÚPŠOŠÓPORA ÚÖÞTÚÚPŠØA OŠÔA LÖÖDA ÞÚÖÞOÚOÚPTŠA TÒA ÚPŠOŠÓPORA ÚLOUÖ SÖŠUÚA ÙTÚA ÖXUÖÚŠORA ÞÙÚÞTÛÖÚA PŠA OÓÓTÚÔOŠÓÖA WPÚÕA ØÖŠÖÚORRYA OÓÓÖÞUÖÔAOÓÓTĽŠÚPŠØAÞÚPŠÓPÞRŐÚĚ
 - ÓÁA GVORÙOÜÖÔAÜŐÖAÖÀÖÓÄPVÖŠÖÛÛA TÀAÜŐÖALÖÖØPÛÜLOŠÜÝÛAÔPÛÓRTÛÙLÓAÓTŠÜLTRÛAOŠÔAÞÚTÓÖÔÙLÖÔAOŠÔAÞÚÖÛÖŠÜÖÔAPŠAUŐPÛALÖÞTÚÜA TÙLAÓTŠÓRÙLPTŠÛAOŒTÙLAÜŐÖAÖÀÖÓÁÖVOZŠÖÛDA TÀAÜŐÖAÔPŨÓRTÛÙLÓAÓTŠÚLTRÛAOŠÔAÞÚTÓÖÔÙLŐÔLAOÛA TÀAÜŐÖAÖŠÔATÀAÜŐÖAÞÖLPTÓA ÓTVŐLÖÔAŒYALŐPÛALÖÞTÚLAEOÛÖÔATŠAÛÙLÓÕAÖVORÙOUPTŠÉAOŠÔ

G Í ÎH IA I ÎJ€JG΀ÏAK I I ÎGHM GHMÑÎ I ÎG€ÑÎKJALOMNO€JÑAÑK <u>BÊAOÀNÀGÀANHGÑÎKJABÇEÃ</u>

United States Steel Corporation Mine Safety Disclosure (Unaudited)

For the quarter ended March 31, 2022

L RTØAĂ Í ØÒØŮÓSA L RTØAÑ ÓŮØŮYAÓTÒ Î ØÓSÌQAGÒ Š RTRÜÙŮÓÌRÞT AĂ L Ñ Î GÀAÏ I À