



ARTS4248

H\Y`<iaUb]h]YgžH\Yb`UbX`Bck

GWkcc``cZ<iaUb]Myg'UbX'@Ub[iU[Yg'#'IBGK '5fng'UbX'GcWU'GW}bWg

GYa YghYf'C bY "# &\$%

7 ci fgY[·]Cj Yfj]Yk

`GHJZZ`7cbHJWh`8YHJ]`g`

'7cbj Ybcfg'

B Ua Y	9a U]`	5j U]`UV]`]m	@cWUhjcb	D∖cbY
FcVYfh6iWX	5		A cfj Yb 6fck b &(-	-',)!,*('

GWXcc`7cbHJWh=bZcfaUh]cb

GWXcc``cZ<iaUb]h]Yg'UbX'@Ub[iU[Yg

@cWUhjcb. `GW&cc``CZJWYžA cfjYb`6fckb`6i]`X]b[ž@YjY``&ž&),

CdYb]b['< ci fg. A cbXUm! : f]XUmž - Ua '! (.() da

D\cbY. Ž*%&-',) %*, %

: UI . Ž*%&'-' ,) ', +\$)

283hat 684 bal 664 to at 255 mil at 255 mil

5HYbXUbW/FYe5HYbX]

7ci fgY[·]8YHJ]`g

7 fYX]hDc]bhg⁻‰⁻

Gi a a UfmcZhXY7ci fgY

H\Y"\i a Ub]hJYg"]g Ub i a VfY``UhYfa i gYXhc fYZYf hc h\cgY i b] Yfg]miX]gW]d]bYg WbWfbYXk]h \i a Ub W `hi fY UbX'j U`i Yg`-]bWi X]b[`\]ghcfmžd\]`cgcd\mž`]hYfUh fYž``Ub[i U[Ygžh\Y Ufhgža i g]WUbX`XfUa U" MYh h\YgY`X]gW]d`]bYg`UbX'h\Y]f'fY`Uh]cbg\]d`\Uj Y'h\Ya gY`j Yg`U'f]W. UbX'Yj c`j]b[`\]ghcfmk]h \b h\Y]bgh]hi h]cb cZh\Y i b]j Yfg]m'i H\]g Wci fgY`]bHcXi Wrg`mci `hc`h\]g`\]ghcfmžZfca `h\Y `9UfmA cXYfb`gh X]U`\i a Ub]hUh]g`hc h\Y]f`YgHUV`]g\a YbhUg`X]ZYfYbHX]gW]d`]bYg`]b'h\Y `b]bYhYbh\!Wfbh fmfYgYUfW.`i b]j Yfg]mhc`h\Y`j Uf]ci g WU``Yb[Yg'h\Y`\i a Ub]hJYg`ZJWYX`]b'h\Y`UHYf`\U`ZcZh\Y`k YbhJYh`Wfbh fmfUbX`Uhh\Y`VY[]bb]b[`cZh\Y k YbmiZ]fghWfbh fm'`H\]g`[YbYU`c[mdfcj]XYg`mci `k]h`Ub`i bXYfgHUbX]b[`cZh\Y`X]j YfgY`UbX'X]j Yf[Ybh Uggi a dh]cbg`UbX`cVYW]j Yg`cZfYgYUfW.`]b`h\Y`\Uh]cb`hc`h\Y`a cXYfb`gW]YbWrg`UbX`h\Y]f`WU]a g`hc`cVYW]j]m Ug`k Y```Ug`]b`fY`Uh]cb`hc`h\Y`UbW]YbhHfUX]h]cbg`cZgY`Z_bck`YX[Y`UbX`gY`Z]a dfcj Ya Ybh'H\Y`U]a `]g`hc U``ck`mci `hc`g]hi UhY`mci f`ck b`fYgYUfW.žVch`\]ghcf]WU``mUbX`]b`U`Wfcgg!X]gW]d`]bUfmWcbhYI h'

5 hih Y WobWi g]cb cZih]g Woi fgY h Y ghi XYbhk]``VY UV Y hc

%" 8]gh]b[i]g\ X]ZYfYbhYd]ghYa c`c[]WU``ck b`Z

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5ggYgga Ybh

5ggYgga YbhHUg_g

5ggYgga YbhhJg_	K Y][\h	8iY'8UHY	GhiXYbhi@YUfb]b[CihMcaYgʻ5ggYggYX
KYY_`m'V`c[g`f%Ł`	&) ı	Bch5dd`]WUV`Y	%ž&ž(
KYY_`m'V`c[g`f&Ł`	' \$I	k YY_'- 'Z '%&	&ž ž(
9ggUmi	()	\$+#\$)#&\$%`\$\$\$`DA	%ž&ž ž(

5ggYgga Ybh8YHJ]`g

5ggYgga Ybh% K YY_`mV`c[gf%Ł

GHJfh'XUHY. "K YY_"&

8YHU]`g. `Ghi XYbhg`XcW a Ybhih Y]f`fYgdcbgYg`hc`UbX`UbU`mg]g`cZfYUX]b[`a UhYf]U`g`X]gW ggYX`]b`h Y`Z]fgh Z]j Y`k YY_g`cZh Y`Wci fgYž`Z]j Y`V`c[`Ybhf]Yg`cZi d`hc`' \$\$`k cfXg`dYf`k YY_"`: YYXVUW_`j]U`fi Vf]Wž`Ug`k Y``Ug Vf]YZ]bX]j]Xi U``k f]hYb`Wca a Ybhg`Ug`fYei]fYX`UbX`[YbYfU``ZYYXVUW_`hc`h\Y`WUgg"

5XX]h]cbU``XYHJ]`g.

Gi Va]gg]cbg[·]UfY[·]Xi Y[·]YUWX[·]Gi bXUmž[·]&' .\$\$ž[·]k _g[·]&! * "

GHUfhXUHY.Bch5dd`]WUV`Y

@Yb[h\.'' \$\$\$`k cfXg`Ž#%\$i

8YhJ]`g. '±b`U`' ž\$\$\$`k cfX`YggUmž`gh XYbhg`YI d`cfY`U`dUfh]Wi`Uf`dUfUX][a žWcbWrdhž'UddfcUW\`cf`a Yh\cX UbX`g]h UhY`]hk]h\]b`h\Y`VfcUXYf`XYj Y`cda YbhcZh\Y`X]gW]d`]bYfgEUbX`h\Y`\i a Ub]h]Yg`=`Ub`cddcfh b]hnhc

Gi Va]gg]cb cZ5ggYgga YbhHUg_g

Ghi XYbhgʻUfYʻYI dYWhYXʻhcʻdi hih\Y]fʻbUa YgʻUbXʻghi XYbhibi a VYfgʻcbʻYj YfmdU[YʻcZh\Y]fʻUgg][ba Ybhgʻ

Hi fb]h]b Gi Va]gg]cb

Zmci YbWci bhYf'U'dfcV'Ya 'k \Yb'UthYa dhjb['hc'gi Va]hmci f'Ugg][ba Ybht\fci [\'Hi fb]hjbž'd'YUgY hY'Yd\cbY'9I hYfbU''Gi ddcfhicb'-',) '' ' %cf'Ya U]`'h\Ya 'cb'<u>YI hYfbU'hY'hgi ddcfh4 i bgk "YXi "Ui</u>"'Gi ddcfh \ci fg'UfY', .\$\$Ua '-'%\$.\$\$da 'cb'k YY_XUmg'UbX'-.\$\$Ua '-') .\$\$da 'cb'k YY_YbXg'fl *) 'XUmg'U'mYUfŁ'' Zmci UfY'i bUV'Y'hc'gi Va]hmci f'Ugg][ba YbhXi Y'hc'U'ZJi `hk]h\'Hi fb]hjb'mci 'a UmUdd`m'Zcf'Ub'YI hYbg]cbžVi hmci a i ghfYhU]b'mci f'hjW_Yhbi a VYf'Zfca '9I hYfbU''Gi ddcfhfU'cb['k]h\ 'Ubmch\Yf'fY'Yj UbhXcW a YbhgŁ'hc]bWi XY'Ug'Yj]XYbWY hc'gi ddcfhimci f'YI hYbg]cb'Udd`]WUhjcb'' Zmci 'Ya U]`'9I hYfbU''Gi ddcfhimci 'k]`` Ui hca UhjWU'`mfYWY]j Y'U'hjW_Yhbi a VYfž'Vi h]Zmci 'hY'Yd\cbY'mci 'k]``bYYX'hc'gdYWJZWU'`mUg_'Zcf'cbY" Hi fb]hjb'U`gc'dfcj]XYg'i dXUhYg'cb'h\Y]f'gmghYa 'gfUh g'cb'Hk]hYf"

; YbYfU``mž'UggYgga YbhiHUg_g'a i ghVY'gi Va]HHXXYYWYfcb]WU``mj]U'Y]H\Yf'Hi fb]h]b'cf'U'A ccX`Y Ugg][ba Ybh''=b`]bgHUbWYg'k \YfY'H\]g']g'bchdcgg]V`Yž']hk]``VY'gHUHX'cb'mci f'Wci fgY'g'A ccX`Y'g]HY'k]H\ U`HYfbUh]j Y'gi Va]gg]cb'XYHU]`g''

@UhY 5ggYgga Ybh DYbU`h]Yg

5b'UggYggYX'HUg_']g'XYYa YX'`UHY']Z]h']g'gi Va]HYX'UZHYF'H\Y'gdYW]ZJYX'Ha Y'UbX'XUHY'Ug'gYhici h']b'H\Y Wci fgY'@YUfb]b['A UbU[Ya YbhGmghYa 'f@A GŁ''

H\Y``UHY`dYbU`hm`]g`H\Y`cgg`cZ)ı `cZH\Y`hcHJ``dcgg]V`Y`a Uf_g`Zcf`H\Y`HUg_`Zcf`YUWX`XUmcf`dUfhiH\YfYcZH\Y k cf_`]g``UHY"`@UHYbYgg`k]```]bWi XY`k YY_YbXg`UbX`di V`]W\c`]XUmg"`H\]g`XcYg`bchUdd`mhc`U`HUg_`H\Uh`]g UggYggYX`Vi hibc`a Uf_`]g`Uk UfXYX"

K cf_'gi Va]httX:Zci fhtYb`f%(EXUmg`UZhYf`h\Y`Xi Y`XUhY`k]``VY`a Uf_YX`UbX`ZYYXVUW_`dfcj]XYX`Vi hbc`a Uf_ k]``VY`fYWcfXYX''`=Zh\Y`k cf_`k ci `X`\Uj Y`fYWY]j YX`U`dUgg`a Uf_`Vi hZcf`h\Y``UhYbYgg`UbX`h\Y`k cf_`]g`U Wca di `gcfmWci fgY`Wca dcbYbhzU`gh XYbhk]``VY`XYYa YX`hc`\Uj Y`a Yhh\UhfYei]fYa Ybh'`H\]g`XcYg`bch Udd`mhc`U`hUg_`h\Uhi]g`UggYggYX`Vi hbc`a Uf_`]g`Uk UfXYX''

K cf_`gi Va]hhYX'hk YbhnicbY'f&&:XUmg'UZhYf'h\Y'Xi Y'XUhY'k]``bch'VY'UWW/dhYX'Zcf'a Uf_]b['cf'ZYYXVUW_ UbX'k]``fYWY]j Y'bc'a Uf_`cf'[fUXY"'=Zh\Y'UggYgga Ybh'hUg_`]g'U'Wca di `gcfm'Wca dcbYbhicZh\Y'Wci fgY'U ghi XYbh'k]``Ui hca Uh]WU``m'ZU]``h\Y'Wci fgY"

GdYWJU``7cbg]XYfUh]cb`5dd`]WUh]cbg

 $\label{eq:milling} \end{tabular} Mci `WUb`Udd`millingYgdYWJU`Wcbg]XYfUh]cb`k \Yb`]``bYgg`cf`ch\Yf`WJfW a ghUbWfg`]bhYfZYfY`k]h\`mci f UggYgga YbhidYfZcfa UbWf"$

G]W_bYggža]gUXjYbhifY`cf`ch\Yf`W]fW a gHubWfg`VYmcbX`mcif`Wcbhfc``aUm

ł DfYj Ybhmci Zfca Wcad Yhjb[UWci fgY fYei]fYa Ybhž

ł?YYdimci Zfca UHYbX]b[UbiUggYggUVYUW]j]mž

ł Ghod moi i gi Va]hh]b[iUggYggUV Y k cf_ Zcf U Wci fgYž

ł `G][b]Z]WUbhmUZYWimci f`dYfZcfa UbWi`]b`UggYggUV`Y`k cf_ž`VY`]hU`Zcfa U``YbX!cZigYa YghYf`YI Ua]bUh]cbž`U WUgg`hYghž`U``UVcfUhcfmhYghž`U`gYa]bUf`dfYgYbhUh]cb`cf`Ubmich\Yf`Zcfa `cZUggYgga Ybh'

: cf'Z fh\Yf'XYHJ]`g`]b`fY`UH]cb`rc`GdYW]U``7 cbg]XYfUH]cb`]bWi X]b[`''K \Yb`rc`5dd`mf'Z''<ck`rc`5dd`mf'UbX "Gi ddcfh]b[`8cW a YbHJh]cb"'d`YUgY`fYZYf'rc'h\Y`GdYW]U``7 cbg]XYfUH]cb`rk YVgh]Y.` \hhdg.##gh XYbH'i bgk "YXi "Ui #gdYW]U`!Wcbg]XYfUH]cb

5WUXYa]W<cbYghmUbX^D`U[]Uf]ga

D`U[]Uf]ga `]g`i g]b[`h\Y`k cfXg`cf`]XYUg`cZch\Yfg`UbX`dfYgYbh]b[`h\Ya `Ug`mci f`ck b"`=hWUb`hU_Y`a Ubm Zcfa gžZca `XY`]VYfUhY`W\YUh]b[`hc`UWW]XYbhU``mWcdm]b[`Zca `U`gci fWY`k]h\ci hUW_bck `YX[Ya Ybh'

IBGK '[fcidg'd`U[]Uf]ga ']bhc'h\Y'Zc``ck]b['WUhY[cf]Yg.

7 cdm]b[..i g]b[.ih,Y`gUa Y`cf`j Yfmig]a]`Uf`k cfXg`hc`h,Y`cf][.]bU``hYI h`cf`]XYU`k]h\ci hUW_bck `YX[.]b[.ih,Y gci fWY`cf`i g]b[`ei chUh]cb`a Uf_g"`H\]g`U`gc`Udd`]Yg`hc`]a U[.Ygž`Ufh`UbX`XYg][b`dfc`YWfgž`Ug`k Y```Ug dfYgYbhUh]cbg`k \YfY`gca YcbY`dfYgYbhg`Ubch\Yf`g`]XYUg`cf`k cfXg`k]h\ci hWfYX]h"

=bUddfcdf]UhY'dUfUd\fUg]b[.'W\Ub[]b['U'ZYk 'k cfXg'UbX'd\fUgYg'k \]Y'a cghmfYhU]b]b['h\Y'cf][]bU' ghfi Whi fY'UbX']bZcfa Uh]cb'k]h\ci hUW_bck `YX[Ya Ybh''H\]g'U`gc'Udd`]Yg']b'dfYgYbHUh]cbg'k \YfY'gca YcbY dUfUd\fUgYg'Ubch\Yf'g']XYUg'cf'k cfXg'k]h\ci hWfYX]h''=hU`gc'Udd`]Yg'hc'd]YW]b['hc[Yh\Yf'ei chYg'UbX dUfUd\fUgYg']bhc'U'bYk 'k \c`Yž'k]h\ci hfYZYfYbW]b['UbX'U'gh XYbhg'ck b'UbU`mg]g'hc'Vf]b['h\Y'a UhYf]U` hc[Yh\Yf''

7 c``i g]cb. 'k cf_]b['k]h 'ch Yfg'Vi hdUgg]b['cZh Y'k cf_'Ug'U'dYfgcb'g']bX]j]Xi U``k cf_''7 c``i g]cb'U`gc]bWi XYg'dfcj]X]b['mci f`k cf_'hc'Ubch Yf'gh XYbhVYZcfY'h Y'Xi Y'XUhYzcf'Zcf'h Y'di fdcgY'cZh Ya d`U[]Uf]g]b['UhUbmh]a Yž'dUm]b['Ubch Yf'dYfgcb'hc'dYfZcfa 'Ub'UWUXYa]WhUg_ž'ghYU`]b['cf'UWei]f]b[Ubch Yf'dYfgcb'g'UWUXYa]Wk cf_'UbX'Wcdm]b[']hz'cZYf]b['hc'Wca d`YhY'Ubch Yf'dYfgcb'g'k cf_'cf'gYY_]b[dUma YbhZcf'Wca d`Yh]b['UWUXYa]Wk cf_''

=ÐUddfcdf]UhY`W]hUh]cb. 7]h]b[`gci fWYg`k∖]WX`\Uj Y`bchVYYb`fYUXžk]h\ci hUW_bck`YX[]b[`h\Y`″gYWcbXUfm´ gci fWY`Zfca`k∖]W\`_bck`YX[Y`cZh\Ya`\Ug`VYYb`cVhU]bYX"

8id`]\WUh]cb`fl`gY`ZId`U[]Uf]ga "Ł`gi Va]hhjb[`mcif`ckb`kcf_ž`]b`k\c`Y`cf`]b`dUfhž`k\YfY`]h\Ug`dfYj]cig`m VYYb`dfYdUfYX`cf`gi Va]hhYX`Zcf`Ubch\Yf`UggYggaYbhcf`\\circf`Ucil BGK `cf`Ubch\Yf`ib]jYfg]hm"

7 cffYWhfYZYfYbW]b[dfUWf]WYg.

• VYHYfa UbU[Y'mcifh]a Y

7 ci fgY GWX YXi `Y

J]Yk WUgg'h]a YHUV`Y

		GhYZUb`7c``]b]ž´´H\Y`:ihifY`cZh\Y` <iaub]h]yg´´`]b 7c``]b]žEbW&][`YaXfZWG`[hWde[f[Wež`@cbXcb. JYfgcž'&\$%+"</iaub]h]yg´´`]b
		FYWca a YbXYX.
		8]dYg\`7\U_fUVUfmži´ <iaub]h]yg`]b`h\y 5bh\fcdcWYbY.`H\Y`7f]g]g`cZUb`9bXif]b[`?Ubh]Ub :UV`Y´``]b`@W/ >[fWbSdk : [efackžJc``'(+žBiaVYfg`' /`'žGdf]b[`/`GiaaYf`&\$%*ž'++!'-+"</iaub]h]yg`]b`h\y
		GhYZUbʻ7 c``]b]ž″F YUX]b[ˈh∖Y`F i]bg. 7 f]h]W]ga ʻUbX ›h∖Y`=XYUʻcZh∖YʻI b]j Yfg]hm;‴]bʻ7 c``]b]žE bW&] [`Y aX fZWG` [hWde[f[Wež@cbXcb.`J Yfgcž&\$%+"
K YY_`+.`%*`5df]``!`&& 5df]`	F YUX]b[8]gWjd`]bY!gdYWjZjWfYUX]b[g B c `WUqq
K YY_`, .`&' `5df]``!`&- 5df]`	F YUX]b[8]gWjd`]bY!gdYWjZjWfYUX]b[g B c`WUgg
K YY_''' \$`5df]`'!`*`A Um	n 5ggYgga Ybh	FYgdcbgYg'hc`Zjfghikkc`gYhg`cZX]gWjd`]bY!gdYWjZjW fYUX]b[g`XiY''\$`5df]`ž`&%\$\$ž`j]U`Hifb]hjb"
		B c `WUgg
	FYUX]b[8]gWjd`]bY!gdYWjZjWfYUX]b[g
K_YY_`%\$.`+`A_Um`!`% A_Um	F YUX]b[8]gWjd`]bY!gdYWjZjWfYUX]b[g
		B c WUgg
	5ggYgga Ybh	F YgYUfVX YggUmXi Yž+A Umž&%\$\$žj]U Hi fb]h]b"
K YY_'%%`%(`A Um!`&\$ A Um	FYUX]b[8]gWjd`]bY!gdYWjZjWfYUX]b[g
		BciWUgg
K_YY_`&&`&%A_Um!`&+ A_Um	5ggYgga Ybh	FYgdcbgYg'hc`ZjbU``h\fYY`gYhg`cZX]gWjd`]bY!gdYWjZjW fYUX]b[g`XiY`&%AUmž`&%\$\$žj`]U`Hifb]hjb"
		B c `WUgg

FYgci fWg

DfYgWf]VYX F Ygci fWfg

K YY_`mfYUX]b[g'UfY'Uj U]`UV`Y'cb'f\Y'Wci fgY'A ccX`Y'dU[Y"

8]gW]d`]bY!gdYW]Z]WfYUX]b[``]ghg`k]``VY`aUXY`UjU]`UV`Y`cb`AccX`Y"`GhiXYbhg`g\ci`X`Wcbgi`hk]h\`h\Y]f <cbcifg`gidYfj]gcfg`UVcihh\Y`gY`YW]cb`Zca`h\Y]f`fYgdYW]jY``]ghg"

FYWca a YbXYX⁻FYgci fWYg

5XX]h]cbU``fYWca a YbXYX`fYUX]b[g`cb`h\Y`hcd]Wg`Wcj YfYX`]b`k YY_g`&!*`UfY`Uj U]`UV`Y`cb`A ccX`Y`Wci fgY dU[Y"

7ci fgY'9j U`i Uh]cb'UbX'8Yj Y`cda Ybh

: cfa U``ZYYXVUW_`Zfca `ghi XYbhg`k]``VY`Wc``YWhYX`j]U`a m91 dYf]YbWY`UbX`k]``VY`i gYX`hc`]a dfcj Y`Z hi fY]hYfUh]cbg`cZh\]g`Wci fgY''`+bZcfa U``ZYYXVUW_`]g`U`gc`j Yfmik Y`Wca Y"

⊨a U[Y[·]7fYX]h

GmbYf[]Yg`]b'GcibX'&\$%*

7F=7CG

7F =7CG Dfcj]XYf 7cXY. \$\$\$-,;