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Topical Report
Tantalum – 2.5% Tungsten Machinability Testing

Federal Manufacturing & Technologies

L. J. Lazarus

KCP-613-8615

Published July 2009

Final Report

Approved for public release; distribution is unlimited.

Prepared under prime contract DE-ACO4-01AL66850 for the
United States Department of Energy

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A prime contractor with the United States Department of Energy under Contract Number DE-AC04-O1AL66850

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KCP-613-8615
Distribution Category UC-36

TANTALUM – 2.5% TUNGSTEN MACHINABILITY TESTING

L. J. Lazarus

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Final Report
L. J. Lazarus, Project Leader

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Illustrations

Discussion

Background

Tantalum tungsten 2.5 (TaW) is considered a flammable metal alloy by the National Fire Protection Association (NFPA). NFPA 484, Standard for Combustible Metals, Chapter 9 Tantalum and Annex E, supplemental Information on Tantalum require cutting oil be used when machining tantalum because it burns at such a high temperature that it breaks down the water in a water-based metalworking fluid (MWF). The NFPA guide devotes approximately 20 pages to this material. The Kansas City Plant (KCP) uses Fuchs Lubricants Ecocut Base 44 LVC as a MWF. This is a highly chlorinated oil with a high flash point (above 200° F). The chlorine is very helpful in preventing BUE (Built Up Edge) that occurs frequently with this very gummy material. The Ecocut is really a MWF additive that Fuchs uses to add chlorinated fats to other non-chlorinated MWF.

Summary

A literature search was conducted to obtain machining parameters for TaW. Some dated information was received from wrought tantalum alloy smelters of these materials (*see* Appendix 2). The information was incomplete and did not include information on new cutting tool materials and coatings. Some papers generated within the NWC complex were found but much of this information was also dated. Conversations with Cabot technical staff revealed that they had been turning bar stock in the 350 SFM (surface feet/minute) range with high rake tools and limited depths of cut. Tool life was short. KCP could increase tool life appreciably by reducing the cutting speed; but machining cycle time would increase dramatically.

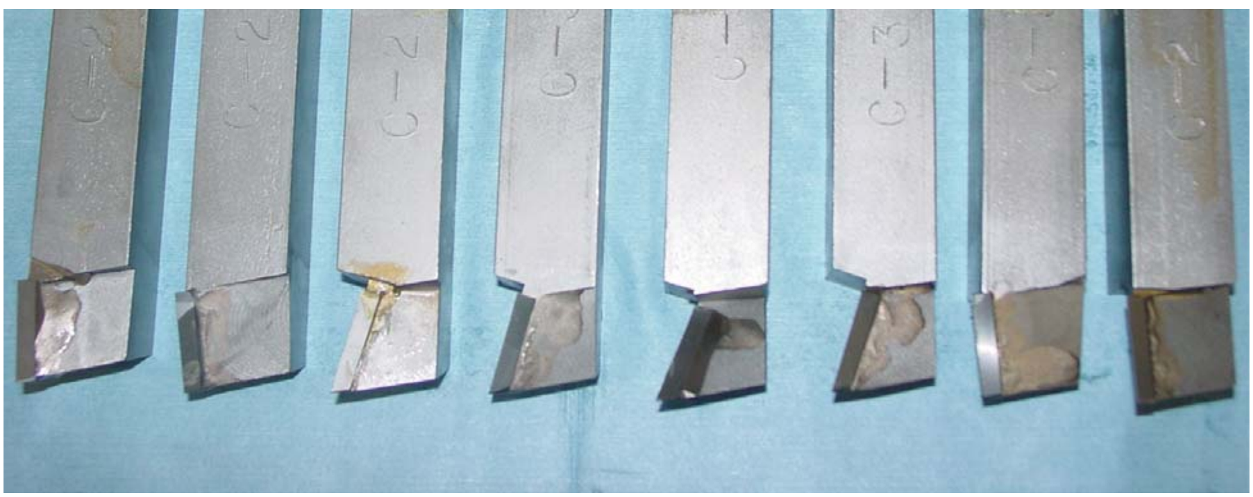
Testing focused on this higher speed and was aimed at increasing tool life with commercially available tooling. Specially designed tooling from commercial vendors usually includes a thousand dollar set up charge plus extended delivery time. Modifying a quantity of inserts in the plant's cutter grind area would significantly increase the insert cost. Developing a mold to press inserts was even more expensive. Large businesses only want to press large quantity of inserts which limits ordering from smaller specialty vendors, thus increasing costs exponentially. Therefore, the decision was made to find a commercially available tool and sacrifice an optimum tool life based on a special geometry.

I also had conversations with the technical staff of Kennametal concerning this material. Discussions with Kennametal technical staff, although having limited experience, recommended two grades which were used in testing. Cutting tool manufacturers did not make high rake inserts (above 18 degrees top rake) in the geometries KCP preferred to use. Recommendations exist for up to 25 degree top rake. This edge is very fragile and easily destroyed when making interrupted cuts. This usually is the first situation faced, when working with any work piece material (wrought, forged, or formed).

Another consideration in the selection process is that cutting tools with a high top rake angle have very delicate cutting edges without much support. They tend to fracture or chip easily especially when inconsistencies in the work piece material structure exists. Intermittent cuts can cause the most damage in the shortest time. Thus, cutting tool manufacturers make special grades for this cutting condition which usually slow the cutting speed down.

The plant required turning tools with as much top rake as possible. In the 1980s KCP ran a test for a process engineer for the IMOG machinability group using brazed tip tools of special design with a variety of rakes. These tools were re-sharpened and used for some of the testing (*see* Photos 1 and 2 following).

1. Variations in Side Rake, Special Brazed Tip Tools (3, -6, 6, -6, 12, -9, -6, 6)



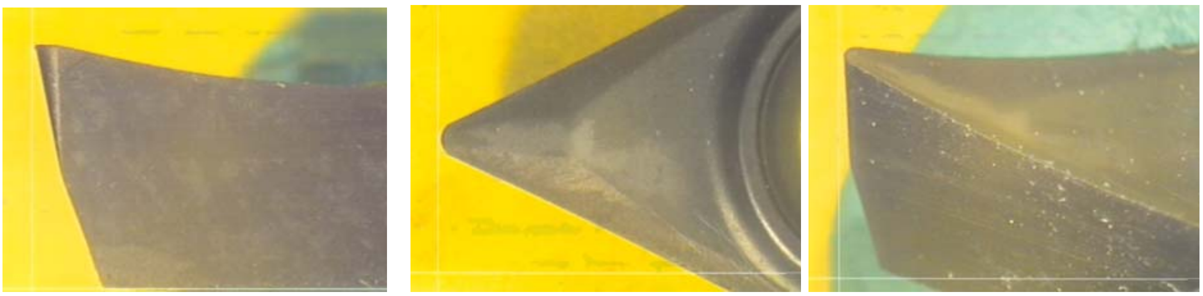
2. Different Top Rakes (from left to right (0, -5, 5, 5, 12, 17, -5, -5))

TaW is a very abrasive material and wears cutting tools very quickly. It has hard particles in a soft gummy matrix. TaW forms a very long continuous chip that will not break into pieces. An unsuccessful attempt was even made to add a chip breaker to the top surface of a high top rake tool. The long continuous "snarled" chip (ISO 3685.1993(E)) often forms a "bird's nest" that will easily break the cutting edge if caught by the tool.

A recently introduced coating by Oerlikon (Balzers) called Alcrona was released prior to this project and is one of the most temperature resistant and hardest coatings for cutting tools (*see*

Appendix 2 for a data sheet which includes all cutting tool coatings). Some of the tools used in this project were coated by Oerlikon. They coated the first group of brazed tipped tools but would not coat a second set because of impurities in the brazing material that contaminated their chamber. Therefore, any additional testing with these tools was stopped.

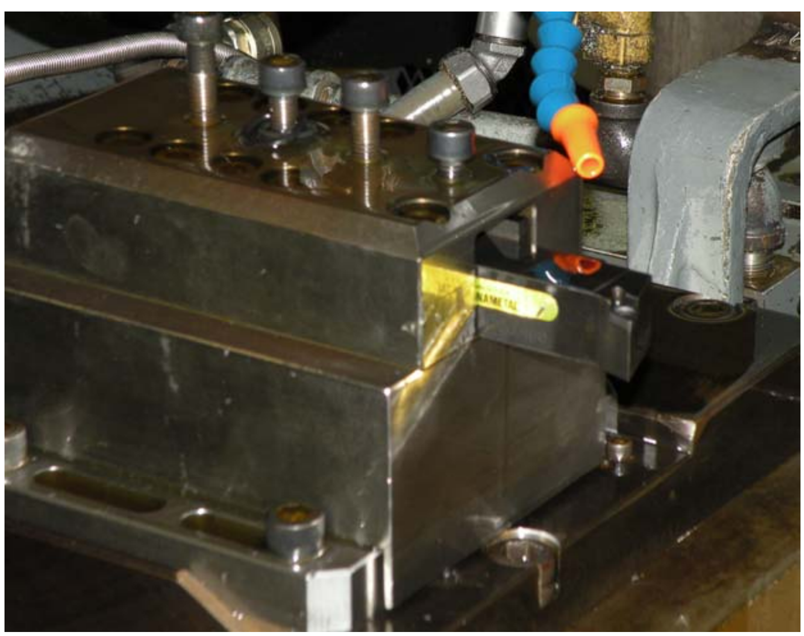
Commercial tools used for this test were obtained from Kennametal. The inserts were DPGT3251HP Grade 5010.



Side Top Cutting Edge

3. Multiple Views of the Kennametal DPGT3251HP Insert
(high rake w/integral chip breaker and sharp cutting edges)

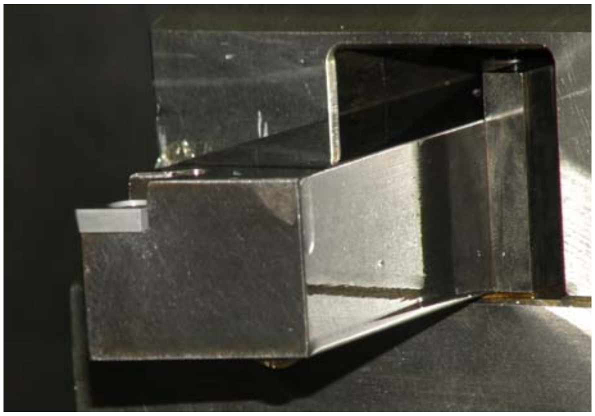
The tool holder was specially designed by Kennametal and used at KCP. It is a modified Kennametal SDJC-L-163 holder. The standard holder has a negative top rake of 3 degrees and side rake of 32 degrees. The special holder has a zero degree top rake and a 17.5 degree side rake. This holder insert combination gave us a top rake of 15 degrees with a sharp cutting edge (no hone). This insert tool combination is typically used for profiling shapes on turning centers and lathes.



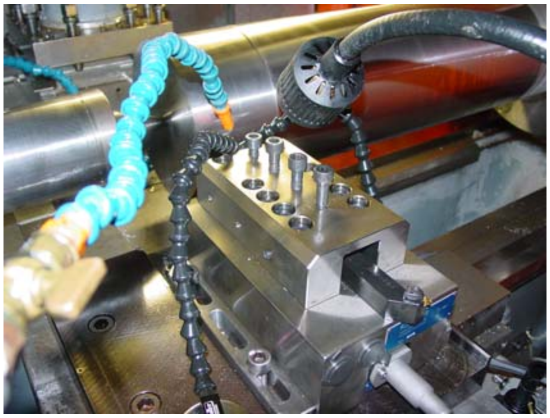
4. Tool Holder Installed in Kistler Cutting Force Dynamometer (Tool overhang is longer than normal to allow clearance & protect dynamometer while generating a shape.)

Oerlikon coated a number of inserts for KCP. Testing revealed the greatest success with Kennametal inserts Grade 5010 which has a TiAlN coating over a very deformation-resistant unalloyed carbide substrate. Oerlikon was able to apply the Alcrona coating on top of the TiAlN coating. This duplex coating of AlCrN on top of the TiAlN increased tool life (~15 to 20%) during turning tests. This combination has been used on other TaW parts and the model makers have stated that this duplex coating provides the longest tool life.

The testing performed leads to the recommendation, if forming a part from this material, that the initial passes be made without the additional coating. Intermittent cuts cause rapid failure of the inserts because hard spots generate in forming and this affects the fragile geometry. Since the high rake geometry of the insert is prone to failure in interrupted cuts, the additional cost for the second coating is not recommended. When using a stronger geometry (lower top rake) insert an increase in tool life was not encountered because the material demands a high shear angle tool to cut.



5. Side View of Cutting Tool Assembly (Note the unsupported cutting edge.)



6. Splash Shield Modified to Control Mist 7. Dynamometer Installed, Rear Turret Position

Photos 6 and 7 from Turning Test Setup, American Hustler Lathe
in Process and Machining Evaluation Laboratory.

Cutting forces were measured using a Kistler Cutting Force Dynamometer that was connected to one of the lab's data loggers. The data logger utilizes National Instruments signal conditioning and data logger modules. National Instruments LabView software supported the display and storage of the digital data. Microsoft Excel software was used for data reduction.

8. Cutting Force Data as Generated During Turning Test Run

Many different configurations of inserts were tried. The Kennametal insert and holder combinations are listed. The best combination of insert and holder were the special design Kennametal holder and the DPGT3251HP Grade 5010 with the Alcona coating.

A Valenite DCMW32.52 modified insert with a change in the top rake to 20 degrees was also tested. No results matched the results of the Kennametal combination. This combination had two factors for consideration. Much care had to be taken to prevent any excess heating of the insert when it was being ground. Also, it was only coated with the Alcrona coating and not the duplex coating.

Milling

A deviation from the regular milling test strategy involved using a single carbide end mill instead of an inserted cutter. This made the wear measurement much more complicated because the wear on every flute had to be measured for each run. When an inserted cutter was used, a single insert was installed and thus only one insert had to be measured.

This was done because process engineering felt that milling would be a secondary operation where a specific feature would be modified. Because of the cost of the material it was determined that the typical operation sequence would be form, turn, and then details (pockets, holes, etc.).

Robb Jack is the carbide end mills supplier for KCP due to superior quality, delivery, and product performance over the years. A high performance end mill currently stocked was selected for these tests (*see* Appendix 2). This is equivalent to the supplier's XR-402-20 4 flute end mill with a TiCN coating on super tuffy (micro-grain carbide).

While these tests were being run an unfortunate error occurred. During normal metalworking fluid (MWF) filling operations in the production machining department, water was added to the special cutting oil. The machine was taken out of operation with the hope that the oil and water would separate. The fluid partially separated and the separated water was removed. The Ecocut oil being used is a metalworking fluid additive designed to add chlorinated fats to MWF mixes. We concluded that the fluid absorbed some of the water and the water that separated removed part of the chlorinated fats.

After this mishap, tool life was reduced 50 percent. Time was not available to order a new batch of MWF and complete the project within the fiscal year. At the time it was unclear what caused the tool life reduction. During data review, comparisons could only be made for tool results of MWF w/water to each other. These tests could not be compared with the previous tests. Viewing the data this way, the determination was made that there was not much difference between the three different end mills tested. However, the end mill made from the super tuffy material seemed to have the most potential of yielding the longest tool live under the operating conditions.

Ta-2.5%W test samples were prepared using Kennametal NGE-1 Inserted End Mill (1.0 inch diameter, 3 flutes), K1003150AN162304C, and ANGT16232PPER3LG in grade KC525M. This combination of holder and insert provided 20 plus degrees of top rake. This combination was not tested because of its large diameter but was very effective on this material. Later tests on other gummy materials has shown this insert holder combination is quite effective.

Drilling Tests

Results indicated that the 118 degree point angle gave superior life over the 135 degree point angle. This matches standard recommendations for ductile materials. A surprising result was the short tool life encountered with the carbide drills. The soft gummy tantalum quickly destroyed the cutting edges.

Appendix A: Summary Data

Turning Data

Test No	File Name	Material	Test Type	Tool Holder	Insert	Grade	Special	Speed SPF	DOC	Feed IPR	Life Min	Cutting Forces (lb) Vertical	Feed	Axial	
		Ta-W/V	T/M/D												
1	5010-01	Ta-W	T	50808438	DPGT3251HP	5010		350	0.01	0.005	Damaged	24	45	15	Had been used for for setup
2	5010-02	Ta-W	T	50808438	DPGT3251HP	5010		350	0.01	0.005	3.8	21	41	15	Possible Damage
3	5010-03	Ta-W	T	50808438	DPGT3251HP	5010		350	0.01	0.005	3.8				Flake Side of insert
4	5411-01	Ta-W	T	50808438	DPGT3251HP	5410		350	0.01	0.005	2.0+				Broke in cut
5	5410-01	Ta-W	T	50808438	DPGT3251HP	5410		350	0.01	0.005	3.8				Flake on side of Insert
6	C2-3-01	Ta-W	T	Braze Tip	Top 13 Side -5	C2-3-01	Special	300	0.01	0.005	4				Chipped
7	C2-5-01	Ta-W	T	Braze Tip	Top 20 Side 17	C2-5-01	Special	300	0.01	0.005	9.75	12.9-24	24.9-38.3	8.9-11.3	Wear
8	C2-5-02	Ta-W	T	Braze Tip	Top 20 Side 17	C2-5-02	Special	300	0.01	0.005	1	11.5	24.2	6.3	Damaged nose
9	C2-5-03	Ta-W	T	Braze Tip	Top 20 Side 17	C2-5-03	Special	300	0.01	0.005	6				.012 Flank .0133 Entry Notch Can be reground
10	KC730-1	Ta-W	T	NE9-DVJNL-163D	VBGT1331HD	730		350	0.01	0.005	1				Chip in Notch
11	KC730-2	Ta-W	T	NE9-DVJNL-163D	VBGT1331HD	730		350	0.01	0.005	3	22.2	38	12	Flank Wear .014
12	NC-1	Ta-W	T	50808438	DPGT3251HP	5010	Alcona	350	0.01	0.005	10	30.6	23.8	15	Wear .010
13	NC-2	Ta-W	T	50808438 plus 4	DPGT3251HP	5010	Alcona	350	0.01	0.005	10				Wear .010
14	NC-3	Ta-W	T	50808438	DPGT3251HP	5010	Alcona	350	0.01	0.005	10.7	20.6-44.8	36-39	8-14	Wear .0109
15	NC-4	Ta-W	T	50808438	DPGT3251HP	5010	Alcona	350	0.01	0.005	< 2.0				Broke off end of insert
16	5410-03R	Ta-W	T	SRDCN2525MO8	RCGT0803M0HP	5410		350	0.01	0.005	2				Wear .0236
17	5010-04R	Ta-W	T	SRDCN2525MO8	RCGT0803M0HP	5010		350	0.01	0.005	2				Wear .0157
18	5010-05	Ta-W	T	SVJBR163	VBGT332HP	5010		350	0.01	0.005	3				Failed, @ 2 min Wear .0099
19	5410-04	Ta-W	T	SVJBR163	VBGT332HP	5410		350	0.01	0.005	3.2				Failed, @ 2 min Wear .0089
20	5010-06	Ta-W	T	50808438	DPGT325.1HP	5010		350	0.01	0.005	3				Failed, Flk Wear .0117
	Added active S additive to cutting oil for NC-5,6,7 runs. Proved unsuccessful. Cause chemical reaction in area of heat of cut														
21	NC-5	Ta-W	T	50808438	DPGT3251HP	5010	Alcona	350	0.01	0.005	2				Flaking - Added SA to oil, Chem reaction
22	NC-6	Ta-W	T	50808438	DPGT3251HP	5010	Alcona	350	0.01	0.005	2				Flaking - Added SA to oil, Chem reaction
23	NC-7	Ta-W	T	50808438	DPGT3251HP	5010	Alcona	350	0.01	0.005	2				Flaking - Added SA to oil, Chem reaction
	Removed modified oil, cleaned sump and refilled with fresh Fuch's oil														
	Valenite uncoated Insert modified in cutter grind. 20 deg top rake ground into top of insert w 1/8 radius chip breaker														
24	LNC-01	Ta-W	T	SDQCR-16-3C	DCMW32.52 Mod	US 10	Alcona	350	0.01	0.005	4				Failed Flank wear .0145
25	LNC-02	Ta-W	T	SDQCR-16-3C	DCMW32.52 Mod	US 10	Alcona	350	0.01	0.005	4				Failed -Flank wear .0133, Entry .022
26	LNC-03	Ta-W	T	SDQCR-16-3C	DCMW32.52 Mod	US 10	Alcona	350	0.01	0.005	3				Failed Chipping
27	LNC-04	Ta-W	T	SDQCR-16-3C	DCMW32.52 Mod	US 10	Alcona	350	0.01	0.005	3				Failed Chipping
28	LNC-05	Ta-W	T	SDQCR-16-3C	DCMW32.52 Mod	US 10	Alcona	350	0.01	0.005	3				Failed Chipping
29	LNC-06	Ta-W	T	SDQCR-16-3C	DCMW32.52 Mod	US 10	Alcona	350	0.01	0.005	3				Failed Flank Wear .0232
30	LNC-07	Ta-W	T	SDQCR-16-3C	DCMW32.52 Mod	US 10	Alcona	350	0.01	0.005	1				Failed Chipping
31	LNC-08	Ta-W	T	SDQCR-16-3C	DCMW32.52 Mod	US 10	Alcona	350	0.01	0.005	2				Failed Chipping
32	BNC-01	Ta-W	T	A16T-SDQPR-4	DPMW432 Mod	US10	Alcona	350	0.01	0.005	2				Failed Chipping

Milling Data

Test No	File ID	Mat	Op	End Mill Designation			Speed SFM	DOC-Axail	Doc-Radial	Feed IPT		
	Sample prep operation with Kennametal 2 flute cutter - profile milling											
		Ta-W	M	K1002150AN 162304C	ANGT1.62.32PPER3LG	525	250	0.4	0.01	0.005	60 inch cu	No visible wear
		Ran various speeds to get in ball park. Started at 152 sfm & .0015 IPT changed at 1 min, 8 min 20 min										
		This tool has variable geometry and opposite flutes in line adjacent flutes not 90 deg.										
38	TICN-1	Ta-W	M	Robb Jack 4 flute End Mill 51105360		S Tuffy-TICN	245	0.1	0.03	0.002	26 min avg wear 0.006/flute	
39	TICN-2	Ta-W	M	Robb Jack 4 flute End Mill 51105360		S Tuffy-TICN	245	0.1	0.03	0.002	30 min .0135 / .0071	
40	TICN-3	Ta-W	M	Robb Jack 4 flute End Mill 51105360		S Tuffy-TICN	245	0.1	0.03	0.002	15 min .0155/.0135 Water in oil	
41	TICN-4	Ta-W	M	Robb Jack 4 flute End Mill 51105360		S Tuffy-TICN	245	0.1	0.03	0.002	Broke at 11 min	
	Removed seperated water from oil - Added 15 gallon fresh oil -											
42	TIN 1	Ta-W	M	Robb Jack C-TS-301-12T		S-Tuffy TiN	245	0.1	0.03	0.002	13 min Avg wear .010 for 3 flutes	
43	TIN2	Ta-W	M	Robb Jack C-TS-301-12T		S-Tuffy TiN	245	0.1	0.03	0.002	13 min Avg wear .016 for 3 flutes	
44	TiALN1	Ta-W	M	Robb Jack C-TS-301-12C		Tuffy - TiALN	245	0.1	0.03	0.002	13 min Avg Wear 0.0145 for 3 flutes	
45	TiALN2	Ta-W	M	Robb Jack C-TS-301-12C		Tuffy - TiALN	245	0.1	0.03	0.002	15 min Avg wear 0.0142 for 3 flutes	

Drilling Data

Test No	Mat	Drill Type	Stores Code	Speed SFM	Feed IPR	Life Holes	Comment
1	Ta-W	118 Deg Pt HSS	50118801	50	0.003	1	.0183/.0173
2	Ta-W	118 Deg Pt HSS	50118801	35	0.001	15	.0151/.0118
3	Ta-W	118 Deg Pt HSS	50118801	35	0.002	20	Spot drill broke leaving debris in hole
4	Ta-W	118 Deg Pt HSS	50118801	35	0.002	25	0.0129/.0164
5	Ta-W	135 Deg Pt Cobalt HSS	50118890	35	0.002	15	@ 10 Hwear .0111/.0100
6	Ta-W	135 Deg Pt Cobalt HSS	50118890	35	0.002	17	@ 15 Hwear .0185/.0148
7	Ta-W	Carbide Drill	50118839	150	0.002	1 Broke 1st hole	
8	Ta-W	Carbide Drill	50118839	105	0.002	5	chipped
9	Ta-W	Carbide Drill	50118839	105	0.002	5	chiped
10	Ta-W	Carbide Drill	50118839	90	0.002	5	broke
11	Ta-W	Carbide Drill	50118839	75	0.002	5	chipped
12	Ta-W	Carbide Drill	50118839	60	0.002	5	chipped
13	Ta-W	Carbide Drill	50118839	75	0.0012	10	Wear .0054/.0042

Appendix B: Supplier Technical Information

oerlikon
balzers

Home › Cutting › **Coatings overview**

Product name	Coating material	Microhardness HV*	Friction coefficient against steel (dry)*	Internal stress (GPa)*	Max. service temperature (°C)*	Coating color	Coating structure	More informations
BALINIT® A	TiN	2300	0,4	-2,5	600	gold-yellow	Monolayer	
BALINIT® ALCRONA	AlCrN	3200	0,35	-3	1100	blue-grey	Monolayer	
BALINIT® ALDURA	AlCr - based	3300	0,35 - 0,40	-3	1100	blue-grey	multilayer, dual	
BALINIT® B	TiCN	3000	0,4	-4,0	400	blue-grey	multilayer, gradient	
BALINIT® C	WC/C	1000 / 2000	0,10 - 0,20	-1,0	300	black-grey	lamellar	
BALINIT® D	CrN	1750	0,5	-1,5 / -2,0	700	silver-grey	Monolayer	
BALINIT® DIAMOND	polycrystalline diamond	8000 - 10000	0,15 - 0,20		600	light-grey	Monolayer	
BALINIT® FUTURA NANO	TiAlN	3300	0,30 - 0,35	-1,3 / -1,5	900	violet-grey	Nano structured	
BALINIT® FUTURA TOP	TiAlN	3300	0,25	-1,3 / -1,5	900	violet-grey	Nano structured	
BALINIT® G	TiCN + TiN	3000	0,4	-4,0	400	gold-yellow	multilayer, gradient	
BALINIT® HARDLUBE	TiAlN + WC/C	3000	0,15 - 0,20	-1,7 / -2,0	800	dark-grey	multilayer, lamellar	
BALINIT® HELICA	AlCr - based	3000	0,25	-3,0	1100	copper	Multilayer	
BALINIT® TRITON	DLC (a-C:H)	2500	0,1 - 0,2		350	black-grey	Monolayer	
BALINIT® X.CEED	TiAlN	3300	0,4	-3,0 / -3,5	900	blue-grey	Monolayer	

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Home › Cutting › Coatings overview › **coating details**

BALINIT® ALCRONA

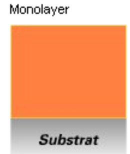
Product name	BALINIT® ALCRONA
Coating material	AlCrN
Microhardness HV*	3200
Friction coefficient against steel (dry)*	0,35
Internal stress (GPa)*	-3
Max. service temperature (°C)*	1100
Coating color	blue-grey
Coating structure	Monolayer
More informations	

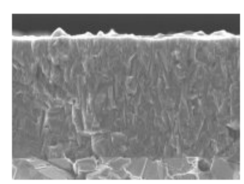
Recommendation

*Carbide end mills and indexable carbide inserts for roughing and finishing
*HSS end mills for roughing and finishing
*Carbide and HSS hobs
*CBN indexable inserts for turning

Coating structure

Monolayer





Coating properties

* Very high abrasion resistance
* High and constant temperature resistance
* Unrivalled oxidation resistance
* Titanium free coating

oerlikon
balzers

BALINIT® FUTURA TOP

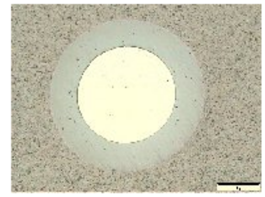
Product name	BALINIT® FUTURA TOP
Coating material	TiAlN
Microhardness HV*	3300
Friction coefficient against steel (dry)*	0,25
Internal stress (GPa)*	-1,3 / -1,5
Max. service temperature (°C)*	900
Coating color	violet-grey
Coating structure	Nano structured
More informations	

Recommendation

For HSS + CC - Tools with high themical stress: Drilling, Turning, Dry machining, HSC, Drilling depth >3xD

Coating structure

Nano structured



Coating properties

* optimized ratio of hardness/internal, stress ,
* higher thermal and chemical stability ,
* better sliding properties ,
* higher wear resistance

Information on the Robbjack Corp. (www.robbjack.com) end mills used in these tests.

X SERIES

XG & XF Tools for Stainless Steels, Hi-temp Alloys and Titanium

This line of solid carbide end mills significantly increases material removal rates in Stainless Steels, High-Temp Alloys and Titanium, while seriously decreasing your cost per part.

The X Series End Mills are engineered using application-specific carbide grades, geometries, and coatings. These patent-pending tools are available in stub and standard lengths, with corner radii or full ball ends.

Advantages

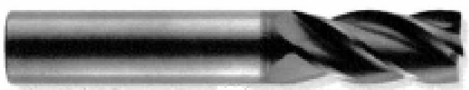
- Reduce Cycle Times
- Increase Part Output
- Reduces Vibration
- Improve Part Accuracy
- Reduce Scrap
- Run at Faster Feeds and Speeds

Features

- Application Specific Carbide Grades and Geometries
- Infinium A Coated
- Tightest Tolerances for Consistent Performance
- 4 Flute for Roughing Operations
- 6/8 Flute for Finishing Operations

Applications

- Stainless Steels
- High-Temp Alloys
- Titanium



XG-400 4 Flute Stub Length

Tool Number	Cutter Diameter DØ	Corner Radius	Shank Diameter dØ	Flute Length L1	Overall Length L	List Price
XG-400-08	1/4"	.017-.019	1/4"	3/8"	2-1/2"	$51.25
XG-400-10	5/16"	.020-.022	5/16"	7/16"	2-1/2"	$58.75
XG-400-12	3/8"	.023-.025	3/8"	1/2"	2-1/2"	$63.55
XG-400-16	1/2"	.025-.027	1/2"	5/8"	3"	$100.60
XG-400-20	5/8"	.027-.029	5/8"	3/4"	3-1/2"	$165.85
XG-400-24	3/4"	.028-.030	3/4"	1"	4"	$246.75
XG-400-32	1"	.028-.030	1"	1-1/8"	5"	$283.85

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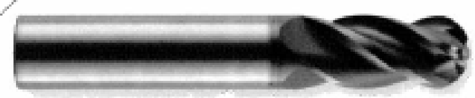


XG-402BN 4 Flute Ball End Standard Length

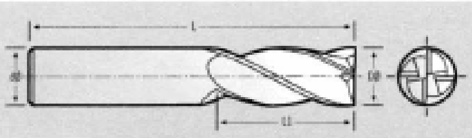
Tool Number	Cutter Diameter DØ	Corner Radius	Shank Diameter dØ	Flute Length L1	Overall Length L	List Price
XG-402-08BN	1/4"	-	1/4"	3/4"	2-1/2"	$59.75
XG-402-10BN	5/16"	-	5/16"	13/16"	2-1/2"	$66.95
XG-402-12BN	3/8"	-	3/8"	7/8"	2-1/2"	$85.50
XG-402-16BN	1/2"	-	1/2"	1"	3"	$119.50
XG-402-20BN	5/8"	-	5/8"	1-1/4"	3-1/2"	$198.90
XG-402-24BN	3/4"	-	3/4"	1-1/2"	4"	$275.75
XG-402-32BN	1"	-	1"	2"	5"	$322.40

XG-402 4 Flute Standard Length

Tool Number	Cutter Diameter DØ	Corner Radius	Shank Diameter dØ	Flute Length L1	Overall Length L	List Price
XG-402-08	1/4"	.017-.019	1/4"	3/4"	2-1/2"	$55.00
XG-402-10	5/16"	.020-.022	5/16"	13/16"	2-1/2"	$57.55
XG-402-12	3/8"	.023-.025	3/8"	7/8"	2-1/2"	$74.20
XG-402-16	1/2"	.025-.027	1/2"	1"	3"	$108.25
XG-402-20	5/8"	.027-.029	5/8"	1-1/4"	3-1/2"	$185.60
XG-402-24	3/4"	.028-.030	3/4"	1-1/2"	4"	$257.35
XG-402-32	1"	.028-.030	1"	2"	5"	$300.25

XG/XF Tolerances

DØ = -.001"/-.002"
L1 = +.060"/-.000"
dØ = -.0001"/-.0002"
L = +/-.060"



XG & XF Speed and Feed

XG-Series Speed and Feed

Material	Surface Footage	1/4 RPM	1/4 in/min	5/16 RPM	5/16 in/min	3/8 RPM	3/8 in/min	1/2 RPM	1/2 in/min	5/8 RPM	5/8 in/min	3/4 RPM	3/4 in/min	1 RPM	1 in/min
Cast Iron															
Ductile	400	6112	28	4890	34	4075	39	3056	43	2445	39	2037	34	1528	30
Gray	525	8022	42	6418	51	5348	58	4011	64	3209	58	2674	51	2006	45
Inconel															
625/718	100	1528	4	1222	5	1019	6	764	7	611	6	509	5	382	5
Steel															
1018/1020	500	7640	32	6112	39	5093	44	3820	49	3056	44	2547	39	1910	34
4130	400	6112	20	4890	24	4075	28	3056	31	2445	28	2037	24	1528	21
4140	400	6112	20	4890	24	4075	28	3056	31	2445	28	2037	24	1528	21
4340	415	6341	21	5073	25	4227	29	3171	32	2536	29	2114	25	1585	22
Stainless Steel															
303	550	8404	31	6723	38	5603	43	4202	48	3362	43	2801	38	2101	34
304	400	6112	17	4890	22	4075	24	3056	27	2445	24	2037	22	1528	19
316	400	6112	17	4890	22	4075	24	3056	27	2445	24	2037	22	1528	19
15-5/17-4	300	4584	13	3667	16	3056	18	2292	20	1834	18	1528	16	1146	14
13-8	300	4584	13	3667	16	3056	18	2292	20	1834	18	1528	16	1146	14
440C	300	4584	13	3667	16	3056	18	2292	20	1834	18	1528	16	1146	14
Tool Steel (Annealed)															
A2	400	6112	17	4890	22	4075	24	3056	27	2445	24	2037	22	1528	19
D2	360	5501	16	4401	19	3667	22	2750	24	2200	22	1834	19	1375	17
H13	400	6112	17	4890	22	4075	24	3056	27	2445	24	2037	22	1528	19
P20	400	6112	23	4890	28	4075	31	3056	35	2445	31	2037	28	1528	24
Titanium															
Com. pure	300	4584	17	3667	21	3056	24	2292	26	1834	24	1528	21	1146	18
6AL-4V	200	3056	9	2445	11	2037	12	1528	13	1222	12	1019	11	764	9
6AL-4V	175	2674	8	2139	9	1783	11	1337	12	1070	11	891	9	669	8

XF-Series Speed and Feeds

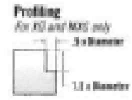
Material	Surface Footage	3/8 RPM	3/8 in/min	1/2 RPM	1/2 in/min	5/8 RPM	5/8 in/min	3/4 RPM	3/4 in/min	1 RPM	1 in/min
Cast Iron											
Ductile	400	4075	29	3056	32	2445	29	2037	34	1528	30
Gray	525	5348	43	4011	48	3209	43	2674	51	2006	45
Inconel											
625/718	150	1528	6	1146	7	917	6	764	8	573	7
Steel											
1018/1020	500	5093	31	3820	34	3056	31	2547	37	1910	32
4130	400	4075	21	3056	23	2445	21	2037	24	1528	21
4140	400	4075	21	3056	23	2445	21	2037	24	1528	21
4340	415	4227	21	3171	24	2536	21	2114	25	1585	22
Stainless Steel											
303	550	5603	31	4202	34	3362	31	2801	36	2101	32
304	400	4075	18	3056	20	2445	18	2037	22	1528	19
316	400	4075	18	3056	20	2445	18	2037	22	1528	19
15-5/17-4	300	3056	14	2292	15	1834	14	1528	16	1146	14
13-8	300	3056	14	2292	15	1834	14	1528	16	1146	14
440C	300	3056	14	2292	15	1834	14	1528	16	1146	14
Tool Steel (Annealed)											
A2	400	4075	18	3056	20	2445	18	2037	22	1528	19
D2	360	3667	16	2750	18	2200	16	1834	19	1375	17
H13	400	4075	18	3056	20	2445	18	2037	22	1528	19
P20	400	4075	22	3056	25	2445	22	2037	26	1528	23
Titanium											
Com. pure	300	3056	17	2292	19	1834	17	1528	20	1146	17
6AL-4V	380	3871	21	2903	24	2323	21	1935	25	1452	22
6AL-6V	175	1783	10	1337	11	1070	10	891	12	669	10

General Guidelines

- Speed and feeds are based on applications with very rigid machine tools, toolholders, and fixturing. Speeds and feeds will vary dramatically depending on the application. Extreme forces can be generated and can cause damage, if not appropriate for the cutting conditions.
- Helical interpolation or ramping should be used to enter pockets.
- For the highest material removal rates and longest tool life profile milling is preferred over slotting (See diagrams below).
- Climb milling is recommended.
- For ball end tools reduce feed rate by 10%

Slotting
For XG and MXG only

Profiling
For XG and MXG only

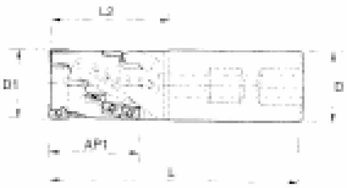


Finish Profiling

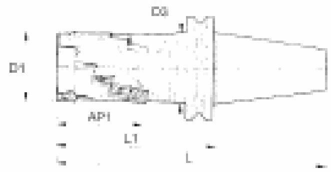
NGE-I End Mills

Insert Size ANGT1.6_ _

- Each flute provides all effective cutting action.
- Positive geometry provides free-cutting action on a variety of workpiece materials.
- Helical design provides uniform cutting action.
- Through-the-tool coolant capability is standard.



Weldon Shank



CV Shank

End Mill with Coolant (Weldon Shank)

effective cutting diameter D1	order number	catalog number	overall length L	head length L2	shank diameter D	number of effective flutes	number of inserts	maximum rpm	AP1	lbs.	spares, information, and accessories: insert screw	Torx driver
.750	1280499	K0751112AN162303C	3.500	1.470	.750	1	4	29600	1.120	<2.00	MS1861	DT8
.860	1509561	K0862112AN162304C	4.000	1.470	1.000	2	6	27400	1.120	<2.00	MS1861	DT8
1.000	1280509	K1002150AN162304C	4.250	1.850	1.000	2	8	25600	1.500	<2.00	MS1861	DT8
1.000	1299033	K1003150AN162304C	4.250	1.850	1.000	3	12	25600	1.500	<2.00	MS1861	DT8
1.250	1280565	K1252187AN162305C	4.500	2.220	1.250	2	10	22900	1.870	<2.00	MS1861	DT8
1.250	1280567	K1253187AN162305C	4.500	2.220	1.250	3	15	22900	1.870	<2.00	MS1861	DT8
1.500	1280586	K1502224AN162305C	5.000	2.720	1.250	2	14	20900	2.240	<2.00	MS1861	DT8
1.500	1280588	K1503224AN162306C	5.250	2.500	1.500	3	18	20900	2.240	<2.10	MS1861	DT8

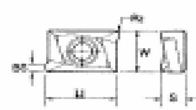
End Mill – CV40 Shank

effective cutting diameter D1	order number	catalog number	overall length L	projection length L1	shank diameter D3	number of effective flutes	number of inserts	maximum rpm	AP1	lbs.	spares, information, and accessories: insert screw	Torx driver
1.000	1280510	K1003R40CVAN1623112	5.417	2.730	1.750	3	9	25600	1.120	2.20	MS1861	DT8
1.250	1280566	K1253R40CVAN1623150	5.810	3.120	1.750	3	12	22900	1.500	2.60	MS1861	DT8
1.500	1280591	K1503R40CVAN1623187	6.167	3.480	1.750	3	15	20900	1.870	3.00	MS1861	DT8

NGE-I Inserts

NGE-I Inserts

ANGT-LG



insert catalog number	ISO catalog number	W inch	W mm	Li inch	Li mm	S inch	S mm	BS inch	BS mm	Rε inch	Rε mm	KC510M	KC520M	KC525M	KC725M	KC620M	KC935M
ANGT1.62.3PPER3LG	ANGT1003PPERLG	.268	6,80	.394	10,00	.142	3,60	.051	1,30	.02	0,5		■	■	■	■	■
ANGT1.62.3PPFR3LGJ	ANGT1003PPFRLGJ							.051	1,30	.02	0,5	■					
ANGT1.62.32PPER3LG	ANGT100308PPERLG							.051	1,30	1/32	0,8		■	■	■	■	■
ANGT1.62.32PPFR3LGJ	ANGT100308PPFRLGJ							.051	1,30	1/32	0,8	■					
ANGT1.62.34PPER5LG	ANGT100316PPERLG							.081	2,07	1/16	1,6		■	■	■	■	■
ANGT1.62.34PPFR5LGJ	ANGT100316PPFRLGJ							.081	2,07	1/16	1,6	■					
ANGT1.62.36PPER7LG	ANGT100324PPERLG							.113	2,88	3/32	2,4		■	■	■		■
ANGT1.62.36PPFR7LGJ	ANGT100324PPFRLGJ							.113	2,88	3/32	2,4	■					
ANGT1.62.38PPER9LG	ANGT100332PPERLG							.145	3,68	1/8	3,2		■	■	■		■
ANGT1.62.38PPFR9LGJ	ANGT100332PPFRLGJ							.145	3,68	1/8	3,2	■					

● ... first choice

◑ ... alternate choice

	KC510M	KC520M	KC525M	KC725M	KC620M	KC935M
steel		◑	◑	●		◑
stainless steel	◑			●		◑
cast iron		●			◑	◑
non-ferrous	●					
high-temp alloys	◑		◑	◑		●

C A B O T   S U P E R M E T A L S

Product Information

CABOT
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Tantalum Processing and Fabrication

Recommendations for Machining Tantalum and Its Alloys				
	Tantalum	Ta2.5W	Ta10W	Ta40Nb
Tool Material	**High Speed Steel:** Type M2, Carbide Type C2	 Same as Tantalum	 Same as Tantalum	 Same as Tantalum
Cutting Speed	**High Speed Steel:** 40 to 60 surface ft/min. (SFM) The heavier the feed and depth of cut, the slower the speed	 25 to 40 SFM Heavier cut, slower speed	 25 to 40 SFM Heavier cut, slower speed	 60 to 100 SFM Heavier cut, slower speed
	Carbide cutting tools: 60 surface ft/min. (SFM) and faster	 40 SFM and faster	 40 SFM and faster	 80 SFM and faster
Feed	Rough 0.008 to 0.015 in. Finish, 0.005 in. maximum.	Same as Tantalum	Same as Tantalum	Same as Tantalum
Depth of Cut	0.015 to 0.060 in.	0.015 to 0.100 in	0.015 to 0.100 in.	0.020 to 0.100 in.
Tool Shape	**Approach angle:** 30k Side clearance, 5 Side rake 5 **Trail Angle:** 45 Back rake, 10 Nose radius, 0.0	20 5 20 25 10 0.005 to 0.030 in.	20 5 20 25 10 0.005 to 0.030 in.	20 5 20 25 10 0.005 to 0.030 in.

Machining: Tantalum has mechanical properties comparable to steel and machining properties comparable to copper. Although there is greater tendency to gall with carbide tools than with high speed tools, both types of tooling are used successfully without galling. Generous use of lubricant (coolant) is essential. Water soluble cutting fluids and vegetable oil work well.

Unannealed tantalum machines better than annealed material because of greater surface hardness. If galling occurs, tears in the surface will be visible. Careful attention to feeds and speeds will prevent galling.

Drilling: Drilling can be done with standard high speed drills. Adequate fluid is a necessary and drill speeds should range from 30 to 40 feet per minute.

Threading: Threading, as on studs by tool point, is usually unsatisfactory. Threads can be easily rolled with standard thread rolling tools.

Grinding: Grinding tantalum is difficult. Most grinding wheels have a tendency to "load," and silicon carbide wheels such as Carborundum 120-T (for rough grinding) and 120-R or 150-R (for finishing) should be used. An adequate supply of cooling water is desirable.

(continued on back)

Tantalum Processing and Fabrication

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Pickling: Immediately following degreasing, but just prior to a finishing, parts should be pickled in 9% HF + 32% HNO3 with the balance distilled or deionized water at room temperature. After pickling, parts should be rinsed in distilled or deionized water and dried. The resultant clean surface will yield better welds with reduced tendency toward porosity and will prevent carbon or oxygen dissolution in the molten pool.

Riveting: Tantalum rivets are made by cold upsetting tantalum wire and rod. Riveting is done cold.

Brazing: For low temperature brazes, the surface of the metal (after proper cleaning) can be wet with tin-lead solders, then brazed. An alternate method is to plate the tantalum with a flash of copper, then braze with the desired brazing material. Brazing of Ag-Mn, Au-Ni, Ta-Ti-V and other compositions may be used.

Resistance Welding: Tantalum sheets are routinely joined to each other by resistance welding, especially thin-gauge sheets, 0.030 in. and thinner. While spot welding in air with a timing of one cycle is usually satisfactory, it is advisable to do resistance welding under water. The water prevents contamination of the weld by oxidation and acts as a very efficient cooling mechanism.

Continuous spot welding for seams is frequently used to weld tubes formed from sheet. While the strength off such a weld is less than that of a fusion weld, the method is satisfactory for applications where internal or external pressures are low. RMWA Class 2 electrodes are satisfactory for resistance welding.

Fusion Welding: Gas tungsten-arc (GTA) and electron beam (EB) welding are standard methods for joining tantalum. In both methods, the workpiece must be clean.

In GTA welding, it is essential to protect the weld as well as the heat affected zone above 260°C (500—F) from air to prevent oxidation and subsequent embrittlement of the weld. This is normally done by providing a supply of inert gas (argon or helium; argon preferred) to the tool area by adding the gas in a fabricated jig or cover box. Copper chill bars are often used to increase the cooling rate and to reduce the size of the heat-affected zone.

Electron Beam welding is commonly used to join thick sections, but can also be advantageous for very thin sections. EB welds in thick sections up to 0.75 in. (19 mm) are narrower and deeper than those produced by other methods. When joining thin sections, the narrow weld zone helps reduce distortion.

Other than ensuring that welding is done with only clean parts, normal electron beam welding procedures are adequate.

Stamping and Drawing: Blanking or punching tantalum parts is routinely accomplished. Normally, steel dies and punches are used, allowing a clearing of 6% of metal thickness between the punch and the die. Aluminum bronze or beryllium copper alloys can be used for the tooling. These materials greatly reduce galling.

Normally, annealed sheet is used for deep drawing operations. Tantalum does not work harden at a fast rate. However, when it does, it is most apparent at the top of the drawn part.

With single draw parts, the depth of draw can equal the diameter of the starting blank. With multiple draws, the first draw should have a depth of not more than 40 to 50% of the diameter of the starting blank. Intermediate anneals are determined by the number of draws involved, the severity of the draw and the desired properties of the finished part. These anneals are usually determined experimentally.

Tantalum can be formed by all the normal sheet-metal forming techniques. The metal, in thicknesses of less than 0.060 in., usually can be bent to 180 degrees on a 1T radius without evidence of failure.

Spinning: Beryllium copper, aluminum bronze and, in may cases, steel tools are satisfactory for spinning tantalum. Yellow soap or Johnson's Wax are suitable lubricants.

Peripheral speeds of approximately 300 feet per minute, with the spinning tool being worked in long sweeping strokes and light pressure are recommended. Using this technique will avoid undue thinning of the metal during forming.

The edges of the part being spun should be trimmed, not only to balance the work, but to remove that part of the metal that is the most highly stressed. While wood forms are adequate, steel is better since tantalum is relatively soft and ductile and will pick up minor surface imperfections from the wood form.

Mechanical Cladding: Tubes and pipes of other metals can be produced where the inside or outside surface of the metal is clad with tantalum sheet to protect against corrosive attack. The application of tantalum sheet is normally done mechanically. While there is not a metallurgical bond, the protective covering of tantalum is adequate for most applications.

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