Structural Changes in Molybdenum Demand

by

Denis Battrum

March 27, 2007

(The author is solely responsible for the information and opinions in the report.)

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marketfriendly, inc.

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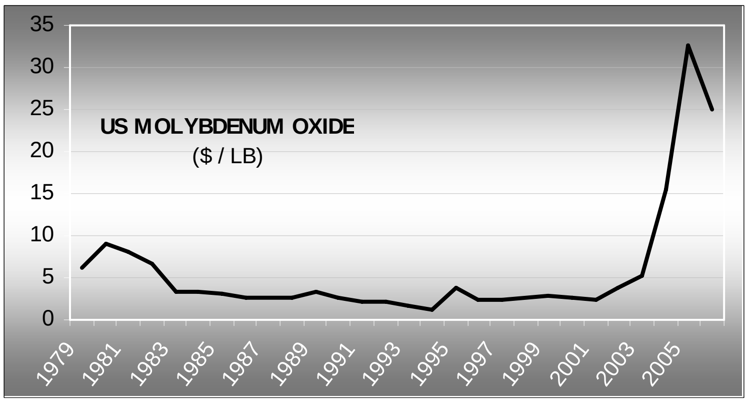
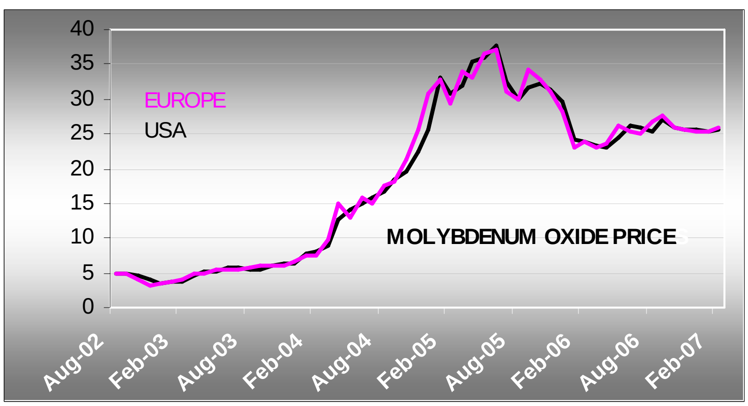




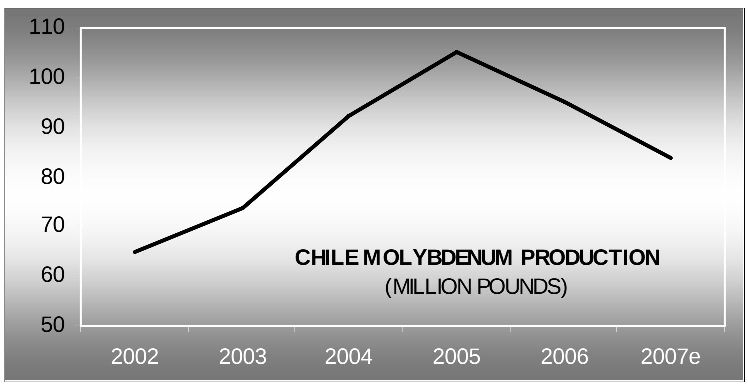
The oxide price had stabilized in the mid-20s range for most of 2006, and the question is whether this is the new market equilibrium or whether molybdenum prices might slip back to earlier “historical” levels.

Molybdenum is undergoing significant structural change on both the supply and demand sides which makes a return to earlier price structures unlikely.

Certain supply side conditions which contributed to depressed pricing in the 1980s and 1990s no longer exist.

On June 11, 1987, the Globe and Mail carried a headline; "Chile – no choice but to produce." Indeed Chile and China were maximizing production looking for hard currency in order to pay for engineering services and materiel to build their economies. Overproduction was rampant. At times in the 1980s and 1990s, inventories had risen to 9-12 months' supply.

Now, however, we have been through a period of high copper and molybdenum prices, and yet inventories and molybdenum production from many by-product producers is declining:



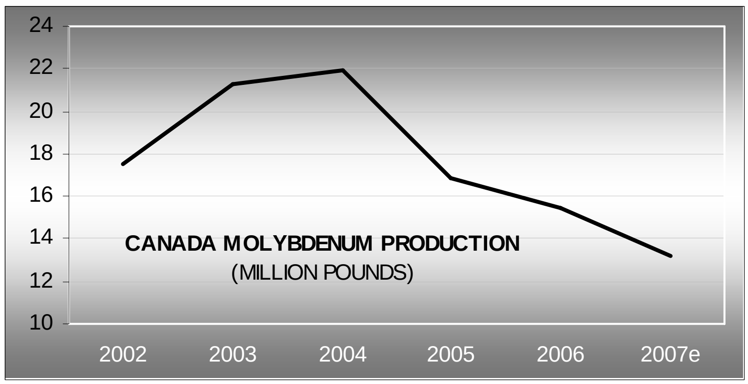
In Chile's case, falling head grades at their largest producer – a mine that has been operating since World War I – have resulted in a loss of 10 million pounds of production last year and possibly another 11 million pounds this year. So while the company continues to maximize copper output, molybdenum output is falling.

This is a radical departure from the earlier reality of the molybdenum industry.

China's molybdenum mine production is falling as well. One estimate has it down by about a quarter between 2002 and 2006. One entire historic mining district appears absent from the news. Production figures out of China are notoriously unreliable, but it appears as though the country wants to retain more of what they produce: China is in the process of adding export tariffs and non-tariff restrictions to molybdenum exports. A spokesman from the Chinese molybdenum producer JDC was quoted in March as saying that he expected a "…quotas system that would further restrict exports out from the country".

Certainly the stellar gains in stainless and carbon steelmaking in China suggest they'll need every pound of molybdenum they can get: China has become the world's largest stainless steel producer with its output exceeding five millions tons in 2006, up 60 percent from 2005. Stainless steel capacity there is on track to reach 12 million tonnes by the end of 2007. China's raw steel production was 418.8 million tonnes in 2006, up 18.5 percent from 2005 and just over one third the world total. In the first two months of this year alone, the output of steel products totaled 79 million tonnes – 25 percent higher year on year.

Canada also has seen significant erosion of its molybdenum production: Several mines have closed. The Highland Valley Copper mine is forecasting an equilibrium level of annual production around 3 million pounds – down from 10.7 million pounds in 2004. For Canada as a whole, the expected 2007 molybdenum production represents just a third of what it was in the late 1970s and early 1980s.

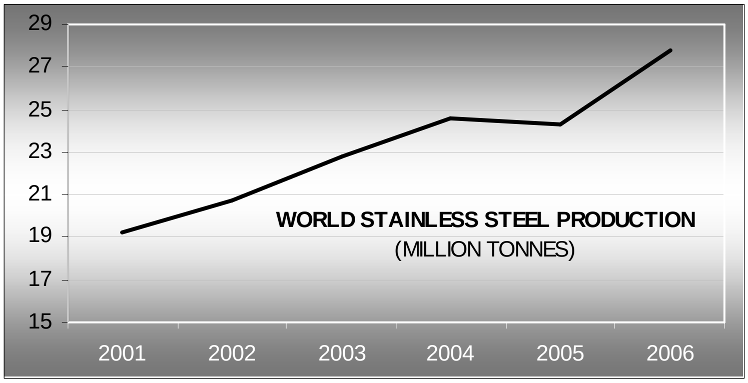


While the chronic oversupply and inventory accumulation that characterized the latter part of the last century has been rationalized (through some very hard times for producers and their employees), demand for molybdenum has continued to rise. Since the mid-1990s, the annual consumption of molybdenum has increased by about 200 million pounds.

These production losses and the demand increase represent the opportunity for new production.

Looking at the demand side, molybdenum has a market niche in stainless steels and in carbon steels. There are other applications – catalysts for example – but steel is the main driver. Many of these steels were on the drawing boards or in a field-trial stage, but not in substantial use while molybdenum languished at “historical” levels.

Stainless and duplex steels



Stainless steel first; this is roughly a 28 million tonne market. We are seeing advancement of so-called duplex stainless steels with more molybdenum and less nickel. Some examples of duplex stainless steels are shown below. Right now, the most common duplex stainless grade produced is 2205, nominally containing 40 percent more molybdenum than the corresponding austenitic stainless – grade 316. (The actual compositions vary somewhat with producer.)

COMPOSITION OF DUPLEX STAINLESS STEELS

UNS Number Duplex Grades	Type	C	Mn	P	S	Si	Cr	Ni	Mo
S31200		0.030	2.00	0.045	0.030	1.00	24.0-26.0	5.5-6.5	1.20-2.00
S31260		0.03	1.00	0.030	0.030	0.75	24.0-26.0	5.5-7.5	2.5-3.5
S32001		0.030	4.0-6.0	0.040	0.030	1.00	19.5-21.5	1.00-3.00	0.60
S32205	2205	0.030	2.00	0.030	0.020	1.00	22.0-23.0	4.5-6.5	3.0-3.5
S32304	2304	0.030	2.50	0.040	0.030	1.00	21.5-24.5	3.0-5.5	0.05-0.60
S32520		0.030	1.50	0.035	0.020	0.80	24.0-26.0	5.5-8.0	3.0-4.0
S32550	255	0.04	1.50	0.040	0.030	1.00	24.0-27.0	4.5-6.5	2.9-3.9
S32750	2507	0.030	1.20	0.035	0.020	0.80	24.0-26.0	6.0-8.0	3.0-5.0
S32760		0.030	1.00	0.030	0.010	1.00	24.0-26.0	6.0-8.0	3.0-4.0
S32900	329	0.06	1.00	0.040	0.030	0.75	23.0-28.0	2.5-5.5	1.0-2.0

Weight percent. “Type” is the common name, not a trademark. 329 is an AISI designation

Commercial production of these duplex steels is still evolving: Baosteel, for example, China’s largest producer, first produced hot rolled 2205 duplex stainless steel strip only this January.

Although the use of higher-molybdenum duplex grades in a given application is not driven solely by the intrinsic value of contained nickel and molybdenum, the recent increases in nickel prices have helped tilt things this way. (Use of the duplex steels involves weight and strength considerations and knowledge of the chemical conditions surrounding the application, etc.) Below are two tables showing the combined intrinsic value of contained nickel and molybdenum for some common austenitic- and duplex stainless grades at different metals prices:

COMPARISON OF DUPLEX AND COMMON AUSTENITIC STAINLESS Ni + Mo VALUE			
GRADE	Ni	Mo	PER TONNE
304	10	0	$4,409
316	13	2.3	$7,000
2304	4.3	0.3	$2,061
2205	5	3.2	$3,968
2507	7	4	$5,291
Nickel $20 / pound Molybdenum $25 / pound			

COMPARISON OF DUPLEX AND COMMON AUSTENITIC STAINLESS Ni + Mo VALUE			
GRADE	Ni	Mo	PER TONNE
304	10	0	$1,323
316	13	2.3	$2,734
2304	4.3	0.3	$701
2205	5	3.2	$2,072
2507	7	4	$2,690
Nickel $6 / pound Molybdenum $20 / pound			

The potential substitution of a duplex stainless like 2304 for austenitic stainless 304 is an interesting one because of the relatively larger market for 304. Molybdenum-bearing stainless steels now represent only 7-10% of the total stainless steel market. Some project examples from Europe follow. The U.S. hasn't yet embraced the substitution to the extent Europe has.

Remember, this is essentially a 0.3 percent Mo product (a "lean" duplex stainless steel) being used in applications that have never used molybdenum-bearing stainless before:

- A stainless steel silo for wheat flour to be fabricated by Desarrollo Agroindustrial del Silo SL in Barcelona, Spain: 500 tonnes of lean duplex sheet to be supplied during 2007 for this project. There was an overall weight savings of 200 tons realized due to the superior strength to weight ratio of the new steel.

- Also replacing 304 stainless with lean duplex stainless steel, the tank maker Emypro, S.A. will furnish 22 tanks for bulk-liquid storage at the Port of Barcelona in 2007. The weight saving is 350 tonnes on a 2,430 tonne project.

- A 66 unit tank farm at the Port of Amsterdam for 2007: The Port has allocated nine hectares in its Westpoort zone to three Dutch companies for the production of biodiesel, bioethanol and biogas from recycled organic waste. The operation will produce 25 million cubic meters of biogas, partially to help fuel on-site processes. 66 tanks with a total capacity of 84,000 cubic meters will use 2,000 tonnes of lean duplex stainless steel in place of 304 stainless.

These duplex steels are still relatively new: Only in March 2006, were duplex steels certified, for example, in drinking water applications:

> 15 March 2006
>
> "NSF International (formerly the National Sanitation Foundation) has announced that NSF/ANSI Standard 61, drinking water system components - health effects, has been expanded to allow additional types of stainless steel as acceptable materials for products used in drinking water applications. NSF/ANSI Standard 61 is the American National Standard that ensures products that come into contact with drinking water do not contribute levels of contaminants that could cause adverse human health effects such as cancer, liver and kidney damage, nervous system disorders, damage to the immune system and birth defects. The NSF/ANSI Standard verifies that stainless steels are highly resistant to leaching of contaminates into potable water. Duplex stainless steel grades 2205, 2304, 2101 and 2003, have been incorporated into the standard. These are in addition to types 304, 304L, 316 and 316L, which have previously been accepted under NSF/ANSI Standard 61."

Space doesn't allow a full examination of the applications for all the duplex stainless steels, but the super duplex stainless steels, those significantly richer in molybdenum, are increasingly specified under corrosive conditions: Desalination, a relatively new demand driver for molybdenum, is just one example:

Main desalination techniques are the multi-stage flash (MSF) process (most common for desalination in large plants, 4,000 cubic meters/day and up, found mostly in the Persian Gulf); the multi-effect distillation (MED) process, and reverse osmosis (RO), the fastest-growing.

- Grade 2205 duplex steel was first selected for evaporators to be installed in the Melittah MSF plant in Libya in 2004. Currently three MSF-type desalination plants are under construction using this combination: Taweelah B, Jebel Ali L2, and Ras Abu Fontas B2 – all to be completed in 2007-08.

- Mitsubishi Heavy Industries will begin production in June of a heavy crude oil-fired thermal power generation and desalination plant in Shuqaiq, Saudi Arabia. The reverse osmosis (RO) desalination plant will have capacity to produce 216,000 cubic meters of desalinated drinking water per day. Grade 2507 duplex stainless steel is specified for high-pressure piping and the energy recovery units.

- SIDEM of France is using a duplex 2304/2205 combination in the world's largest MED-type desalination plant to date, Al Hidd in Bahrain, to be completed this year. Outokumpu, a major duplex stainless producer, pioneered this DualDuplex™ concept for desalination using two different types of duplex stainless steel in the structures of evaporators – the 2205 grade for parts exposed to the more corrosive conditions, and a lean duplex like 2304 for parts elsewhere.

The South Australia government is working with BHP Billiton on building the state's first desalination plant, on Spencer Gulf. It will be used to supply water to the Olympic Dam uranium mine as well as to supplement water supplies to upper Spencer Gulf towns and the Eyre Peninsula. Desalination is required for an increasing number of mining operations worldwide.

Australia just announced 17 coastal locations for potential power generation, which would seem likely candidates for desalination. Spain reportedly plans to build 30 new desalination plants in the next few years and Spanish stainless steel producer, Tubinox, reported this year that it will double capacity by 2010, to “take advantage of the growing desalination industry”.

The reduced availability of process water around the world and a requirement for desalination at an increasing number of mining operations highlights the added difficulty, time and cost to bring new mineral production online, and the competitive advantage of resources located in areas where there is water.

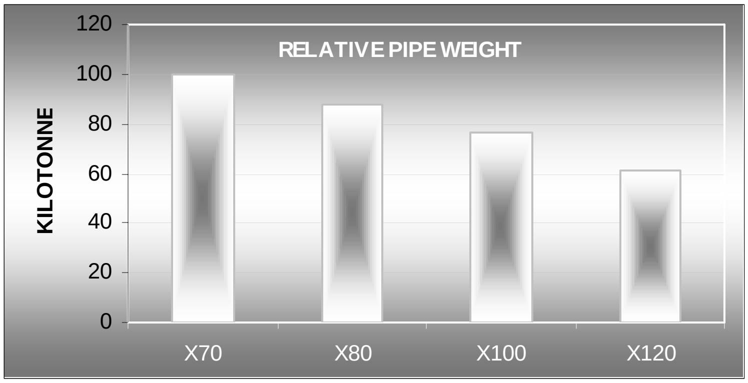
Carbon steels

Carbon steel production in 2006 was over 1.2 billion tonnes. This is 40 times the size of the stainless market and molybdenum is beginning to establish a foothold in carbon steels through the development of Advanced High Strength Steels (AHSS). These revolutionary developments in steelmaking are allowing steel to recapture ground lost to aluminum and plastics over decades. Given the size of this segment relative to stainless, the potential for increased molybdenum consumption is truly extraordinary.

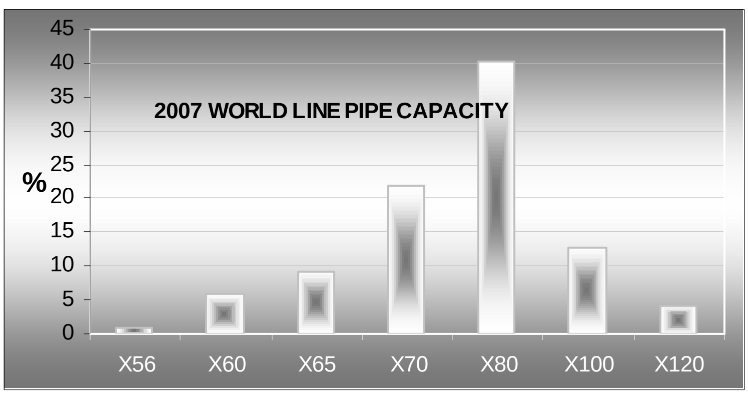
In this category, we see an increasing number of applications for molybdenum:

One is pipeline steels containing in the order of 0.25 percent molybdenum. Engineering studies have shown significant project cost reduction using advanced high strength steels in pipelines, even with the increased unit price of the product. The reduced wall thickness allowed by these new steels requires less steel overall for the pipeline, reduces transportation costs, and lowers construction costs. Tremendous logistical value can accrue as well when you consider that some of the legacy pipeline pipe is so heavy that each 40-ft. piece (“joint”) requires a separate truck –132 truckloads per running mile!

Relative material weight savings for various API grades of steel pipe are shown below, based on a hypothetical 100,000 tonne pipeline project.



Currently, molybdenum demand in this application is limited by the availability of capacity: The vast majority of the world's pipe mills have yet to upgrade to the newer grades like X100 and X120, which contain higher levels of molybdenum.



Nippon Steel, for example, is so convinced that X120 pipe is the product of the future, they're setting up a separate division to handle it, and adding compressed gas cylinder production in the same material.

North American auto producers are increasing their usage of advanced high strength steels each year under a program that will see the material requirement expand relative to that of legacy steels by a factor of 4 times over the next ten years.

Advanced high strength steels give their cars the 5-star crash safety test ratings that have become so important in automotive marketing. The new steels have made it possible to achieve better safety structures without adding weight.

The same goes for Europe where all carmakers want high EuroNCAP crash test ratings. And after this push to satisfy consumer demand for safer cars, the European Union's renewed focus on reducing vehicle carbon dioxide emissions is again highlighting the weight-saving potential of AHSS.

Arthur D. Little notes that this weight reduction can improve fuel economy about 5 percent and will cost only 212 additional euros per car. The consulting firm claims the new steels will yield more fuel savings than several powertrain technologies: variable valve timing, turbocharging and cylinder deactivation.

Weight reduction also allows lighter brakes and less powerful engines.

Automotive sheet steels in Asia are increasingly being upgraded to AHSS following the European and US lead. In January-February 2007, China produced 1.38 million automobiles units, an increase of 21.5 percent year on year. In 2006, China produced 7.28 million units, an increase of 27.6 percent over 2005.

NUCOR has demonstrated the ability to produce an advanced high-strength steel sheet, called 590 Mpa dual phase steel, from scrap.

Power generation

The IEA predicts that by 2030, with newly accommodative policy from various governments, nuclear generating capacity will have grown to 519 gigawatts (GW), from 368 GW now – a 41% increase. Nuclear power plants contain a number of heavy components. A partial materials list calculated by the U.S. Department of Energy (DOE) is shown below. (This list does not include over 100 pumps, 9-18,000 valves and about 130 miles of pipe, per plant.)

GENERATION III+ NUCLEAR REACTOR COMPONENTS		
ELEMENT	NUMBER PER PLANT	UNIT WEIGHT (TONNES)
REACTOR PRESSURE VESSEL	1	1,200
STEAM GENERATOR	2	730
MOISTURE SEPARATOR REHEATER	4	440
STEAM TURBINE GENERATORS	3	550
LOW PRESSURE TURBINE	3	250
GENERATOR STATOR	1	500
GENERATOR ROTOR	1	250
CONDENSERS	3	660

NOTES:
1. Not all types of reactors use all these components. Data cover these designs: General Electric (GE) Economic Simplified Boiling Water Reactor (ESBWR); Toshiba-Version, GE-Design; Advanced Boiling Water Reactor (ABWR); Westinghouse Advanced Pressurized Water Reactor (AP1000), and the Framatome ANP (Areva).
2. Each Gen III unit will use either 2 steam generators or 2-4 moisture separator reheaters
3. Each steam turbine generator would have up to 3 condensers
4. Quantities are listed as maximum per plant

There are a large number of molybdenum-bearing alloys used in nuclear plant components and piping. For example, there are more than a dozen condenser tube alloys, containing between 4-5% molybdenum on average.

Nuclear power has become a demand driver for molybdenum even in the absence of new construction. 316 stainless pipe (2-2.5% Mo), for example, is being specified for replacement piping for fluids running over 200°C, and since late 2005, the use of duplex stainless steel S32205 (3-3.5% Mo) has been approved for replacement of regular mild steel pipe (no molybdenum) in cooling water intake where any kind of corrosion is evident – including microbiologically influenced corrosion (MIC) from fresh water.

Generation IV reactor technology indicates an enhanced molybdenum utilization due to the hotter and more corrosive conditions under which these plants are designed to operate; and should combined hydrogen production be achieved with these facilities, still more molybdenum usage is indicated.

The majority of power plant component weight – heat recovery steam generators, turbines and pipe – show commonality in nuclear power, oil- or coal-based generation. Hence, molybdenum offers investors a natural energy hedge – regardless of the energy choice society makes for its electricity generation.

Catalysts

There is extraordinary new growth occurring in catalyst demand for the production of ultra low sulfur diesel (ULSD). Achieving the reduced sulfur specification of less than 15 ppm more than doubles the use of catalyst in the same refinery. About 95% of refiners use either a nickel-molybdenum catalyst or a cobalt-molybdenum catalyst for sulfur removal in the ULSD application.

ULSD is the single largest environmental mandate since the removal of lead from gasoline 25 years ago, and the full impact on molybdenum demand has yet to be felt:

Since October 15, 2006, most of the diesel fuel sold in stations in Canada and the United States has been ULSD. The first diesel engines specifically designed for ULSD fuel are in 2007 vehicles. The EPA is mandating a June 2007 500 ppm sulfur cap for off-road diesels, and then a June 2010 deadline for all highway trucks and off-road diesels (except locomotive and marine, and small refiners) to conform to the 15 ppm sulfur limit. Two years later, the ULSD requirement will extend to locomotive and marine diesels, and by June 2014 the ULSD cap will apply to everyone.

The overall diesel demand growth rate in the last three years has been about double that of gasoline: roughly 3.5-4% per year.

The number of diesel-fueled cars and light trucks sold in the US has grown consistently in the last 10 years and is up 80% in the last six. Global demand for diesel light vehicles is expected to nearly double over the next decade, increasing to 29 million unit sales according to J.D. Power and Associates. Global Insight predicts diesels will expand market share even in Europe, where there is already significant market penetration.

The U.S. EIA has calculated that if gasoline demand grows by 1% a year for the next 25 years, the United States will need to build 16 new 200,000 barrel per day (b/d) refineries just to maintain the present level of gasoline production and imports. But if instead U.S. motorists bought advanced diesel cars, only six new refineries would be needed.

Military

The military driver has been accelerating. It is noteworthy that China's recent increase in molybdenum export tariffs and other non-tariff restrictions coincided with the announcement of a serious new 5-year defense spending plan: President Hu Jintao has called for the building of a "strong and modern navy" and generally the central party plans eventually to double military spending as a percentage of GNP (which is itself growing at 10 percent a year).

The realigned spending on the navy seems likely to follow US research and development of a 0.5 percent molybdenum steel for hulls and superstructure. The NAVSEA Warfare Center in West Bethesda has demonstrated weight savings, increased speed and increased ballistic protection using these steels.

Rearmament in response to China's move has Japan (among other things) replacing its air force: Japan will buy 250-300 new military aircraft, with a decision this summer regarding the supplier. The choice is between the Eurofighter, at about $126 million each, and the F-22 at about $200 million each. The augmented requirement for molybdenum-containing superalloys for the jet turbines appears locked in.

Armor plate production is at a high level and looks to increase. The armor can contain molybdenum at levels comparable to X-100 pipeline steel, around 0.3 percent Mo, and some US plate producers plan to introduce a 0.5% Mo product. The armor plate industry refers to it as Ultra High Hardness Steel.

What the media refer to as "bunker buster" bombs, called penetrators in the industry, are becoming increasingly popular, and they use molybdenum in the casings. Traditional penetrator materials, like SAE 4340 steel (0.2-0.3% Mo), are being replaced with, newer, higher molybdenum materials, such as AF-1410, HY-180, and Aermet-100. (See table below.)

PENETRATOR CASINGS

Grade	Mo (%)
SAE 4340	0.2-0.3
AF-1410	1
Aermet - 100	1.2
Hy-180	1

AF-1410 is a 1,500 Mpa steel. If we used the same designation as line pipe, it would be like an X-220.

There are other military applications for molybdenum in steels, alloys and lubricants too numerous to cover here, but what's important to note is that governments worldwide are rebuilding their armed forces and using an argument for domestic "security" to justify spending above and beyond traditional defense programs. This enhanced re-armament drives an increased demand for molybdenum – at a level distinctly heightened relative to the period of "historical pricing" in question.