

## National Security Assessment of the Ball and Roller Bearing Industry

### Product Descriptions

Antifriction (or rolling) bearings are mass produced precision components. They consist of rolling elements sandwiched between inner and outer rings. The rolling elements include balls, cylindrical rollers, barrel or spherical shapes, tapers, and elongated needle like rollers. The rolling bearing takes its name from the type rolling element it employs. The outer ring is usually attached to a machine's structure, while the inner ring or bore is attached to a rotating shaft so that the rolling elements roll in the opposite direction of the shaft. The load is carried or transmitted across the rolling elements. Precision levels to the millionths of an inch are not uncommon and are critical to reduce vibration, noise, heat, and bearing wear.

Probably well over 150 thousand distinct bearing part numbers are in use worldwide, although many of the differences are somewhat superficial. Actually, only about two thousand bearing part numbers are manufactured in high volumes (i.e., mass produced), and these are the most actively traded across international borders. Bearing sizes range from as small as only 1 millimeter in diameter to nearly 40 feet across, however, the great majority lie between about 0.5 and 8 inches.

Rolling bearings are used throughout the durables goods sector to reduce friction. Very low friction coefficients are maintained over a wide range of specified rotational speeds, significantly reducing energy requirements and greatly increasing machine efficiency and precision. Markets are as varied as automobiles, airplanes, hand tools, machine tools, computers, conveyors, construction equipment, or virtually any item having rotating parts. Rolling bearings are of critical importance in defense applications, especially where high precision and speed are crucial to weapon system performance, such as gas turbine engines, missile guidance systems, tank turrets, and noise quiet submarine equipment.

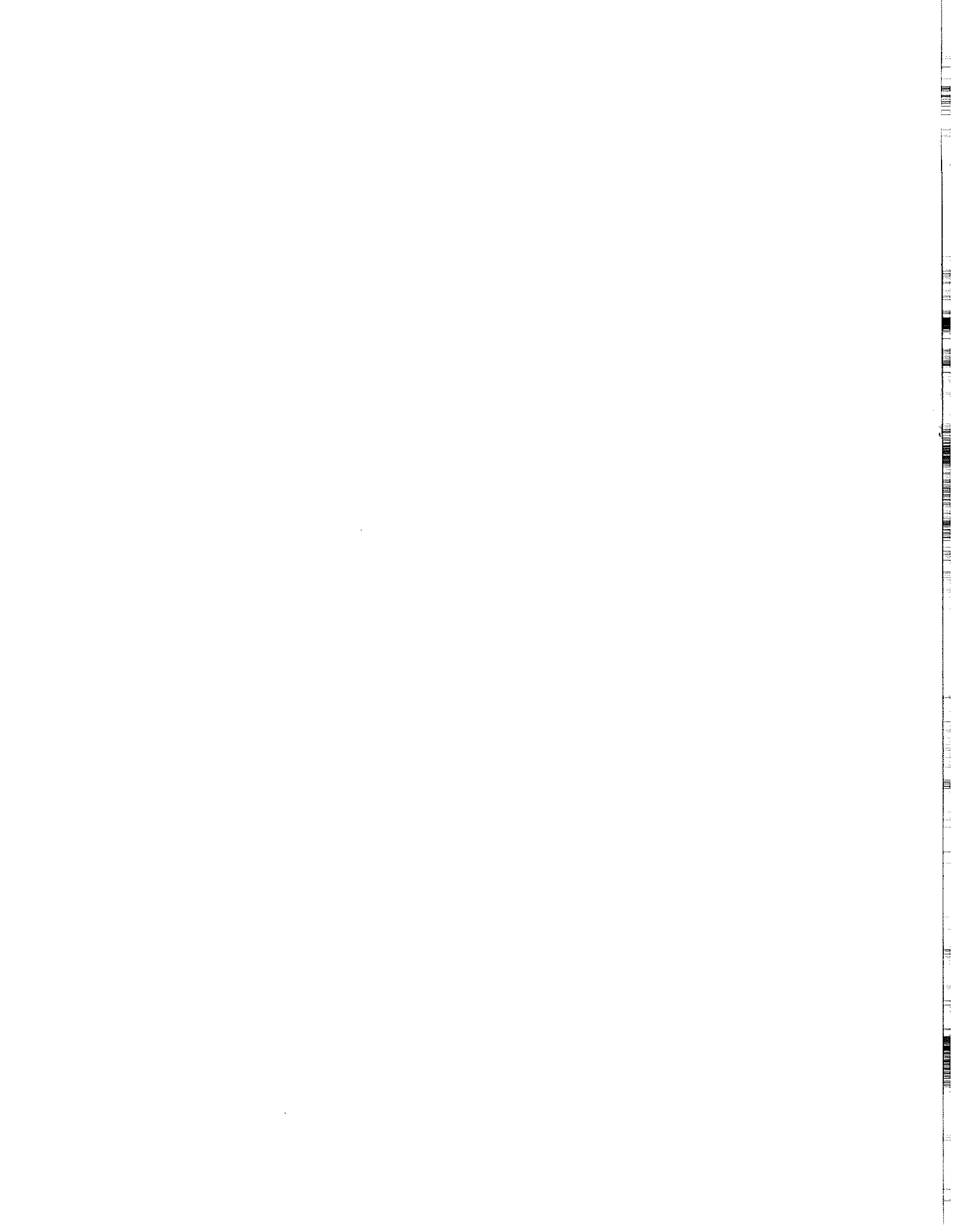
Rolling bearings are identified according to the type of rolling element they contain as well as by their size and precision level. Superprecision bearings tend to be the most problematic and generally have the longest lead times, however, larger sized regular precision can cause problems as well. Ball bearings have the least friction of the bearing types because of the "point" contact between the rolling element and raceway surfaces. They are also the easiest to make and have the lowest per unit price. Roller bearings have "linear" contact at the rolling surfaces, which sacrifices speed for greater load carrying capability. Roller bearings, with the exception of needle bearings, tend to be larger and



much more expensive than ball bearings. Roller bearings are normally the choice for larger equipment - trucks, forging presses, mining equipment, etc.

Some typical types and applications of ball and roller bearings:

1. Miniature and Instrument Bearings (i.e., radial ball bearings under 30mm in outside diameter) - small electric motors, computers, photocopy equipment, communication equipment, power hand tools, gyroscopes, dental drills, instrumentation
2. Single Row Deep-Groove Ball Bearings (i.e., radial ball bearings generally over 30mm and under 200mm in outside diameter) - centrifugal pumps, conveyors, electric motors, generators, machine tools, automobile and truck components
3. Maximum Capacity Ball Bearings (i.e., ball bearings with the maximum compliment of rolling elements; can carry more load) - industrial lift trucks, construction machinery, truck and farm equipment components, heavy duty pumps, gear reducers
4. Angular Contact Ball Bearings (i.e., non-radial ball bearings that counter axial thrust in one direction; often mounted in opposing pairs) - gear drive clutch release, compressors, wheel hubs, printing presses, pumps, electric motors, machine tools
5. Double Row Ball Bearings (i.e., radial ball bearings with two rows that distribute load over a wider area; able to carry more load) - automotive water pumps, pumps, compressors, automotive pinions, power transmissions
6. Integral Shaft Ball Bearing (i.e., typically a double row radial ball bearing with the inner raceways built into the rotating shaft; saves space) - automotive water pumps, washing machines, computer disc spindles, wheel hub units
7. Self-Aligning Ball Bearings (i.e., ball bearings whose outer ring raceway structure allows lateral displacement; needed where rotating shafts can bend under stress) - farm equipment, power transmissions, heavier equipment
8. Thrust Ball Bearings (i.e., non-radial ball bearings with raceways perpendicular to axis of rotation, oppose axial thrust in both directions; prevent axial movement) - machine tools, three-wheeled vehicles, valves, cranes, tapping machines, mining machines



9. Cylindrical Roller Bearings (i.e., rollers width and length about equal; carries radial load) - rolling mills, machine tools, electric motors, printing machinery, pumps, oil field machinery, railway equipment

10. Needle Bearings (i.e., rollers length four times or more the width; can carry very high radial load in small diameters) - automotive steering columns, planetary gears, machine tools, printing machinery, air compressors, textile machinery, woodworking machinery, gear drives, universal joints

11. Tapered Roller Bearings (i.e., rollers tapered or conical; designed to carry radial and thrust loads, often installed in opposing pairs) - wheel units, automobiles, differentials, trucks, mail equipment, machine tools, railroad wheel boxes, farm machinery, milling machines, printing machinery, textile machinery, turret lathes, valves, trailers, foundry equipment

12. Spherical Roller Bearings (i.e., rollers arced along width that self-align with rotating, bending shaft under extreme stress; can carry very large loads) - construction equipment, crushers, power shovels, steel rolling mills, pulverizers, textile machinery, mining equipment

### **Manufacturing Process**

Rolling element bearing production involves three parallel production processes which are joined in the matching and assembly of the various bearing parts. These processes are: 1) production of the inner and outer rings; 2) production of the rolling elements; and 3) production of retainers and other accessories, such as oil seals and dust shields.

Ring production - The ring blanks are initially either forged to approximate size for subsequent machining or machined directly from tubing or bar stock. Larger diameter rings, beginning at about 6 to 8 inches, require forging. The machined rings are then hardened and tempered to the proper degree of hardness and finished to final dimensions by grinding. The grinding operation on the sides or faces of the rings is accomplished with surface grinders to make them parallel. The outside diameters are then ground on centerless grinders to square them with the faces. Race groove curvatures are next finished by form, plunge, or oscillating grinding. In addition, the load carrying surfaces are generally further refined by lapping, polishing, or honing with fine abrasives. After final finishing, inner and outer rings are matched dimensionally to a set of rolling elements to give the specified radial and axial clearances.



## Process Description

1. Automatic Screw Machining, or "Green Machining" - After a sample of the material has been metallurgically tested and approved, bar or tube stock is fed into a screw machine which cuts the tubing into rings of roughly correct dimensions. In the same operation, inner and outer grooves are cut into the raceways for the rolling elements. Rings with diameters over roughly 8 inches are forged as a screw machine is no longer economical. For low volume production lots, many manufacturers are now using CNC turning machines, which greatly reduce set-up time when changing part dimensions. In another process, needle bearing cups of smaller diameters may be "drawn" from low carbon sheet steel on high speed presses. Secondary operations are next performed to add identification markings to the rings, and often to make shield or seal cuts, and on occasion special features such as oil channels, or notches to facilitate mounting.

2. Heat Treatment - All heat treating processes are based on time-temperature cycles. These cycles include three basic steps: 1) heating to a specified temperature, 2) soaking at the required temperature to ensure uniform temperature throughout the part, and 3) cooling at a prescribed rate. The total heat treating process is extremely important in maintaining the dimensions initially manufactured into the bearing.

Standard bearing steels, AISI 52100 and AISI 440C, are generally through-hardened to Rockwell C 58-62 by heating to the proper temperature which assures the complete formation of an "austenitic" crystalline structure. The alloy is then cooled to room temperature and below, transforming it to a martensitic crystalline structure, a hard, strong and wear resistant crystalline form of steel.

Not all the austenite is transformed to martensite and a small percentage remains which is often referred to as "retained austenite". This residual is unstable and will gradually transform over time to the martensitic phase. High temperatures will accelerate this transformation. Since the martensite form of the steel occupies a larger volume than the austenite form, the part will actually grow dimensionally. This dimensional growth can have serious effects on bearing performance and life.

In order to achieve a high degree of dimensional stability, with minimum dimensional growth, it is necessary to cause the residual austenite to transform to martensite before the parts are finished to final dimensions. The rings, therefore, are processed through a multiple number of low temperature cooling (quenching) and heating (tempering) cycles to obtain dimensionally stable components. This process causes a decrease in hardness





and tensile strength, but important increases in toughness and reduction of residual stresses are obtained.

3. Grinding - The grinding and finishing operations remove very small amounts of metal, but are absolutely critical to obtaining the precision dimensional tolerances required for antifriction bearings. Several surfaces of the ring are ground in a sequential process as follows:

a) Face Grinding - The two sides of the ring (i.e., the opposite faces) are ground on a double disc grinder to be parallel. Additional grinding for final size and smoothness is done on a face lapping machine. These operations finish width tolerances and parallelism.

b) Centerless Grinding - Using the faces as a reference, the rings are stacked together and their outside surfaces are ground to near perfect roundness on a through feed centerless grinder. This operation finishes to diametrical tolerances of .0001 inch, squareness with the faces to .00005 inch, and roundness to .000025 inch (i.e., 25 one millionths of an inch).

c) Bore and Race Grinding - Using the finished faces and outer diameters as a reference, the bores (insides) of the inner and outer rings and the raceway grooves are finished ground. Again, holding close dimensional and geometrical accuracy.

d) Raceway Finishing - The raceway grooves of both inner and outer rings are honed to remove the asperities left by grinding. Smooth running grooves are prerequisite to insure low torque and quiet bearings.

4. Assembly and Cleaning - The assembly of bearings is exacting, making simple automation difficult and impractical for small production lots. The assembly operation is very labor intensive and requires manual dexterity, good vision and attention to detail to perform well. Bearings are often assembled in a specially controlled environment which is free of contamination (Class 100 Clean Room for small ball bearings). Inner and outer rings must be accurately gaged and matched with exact size rolling elements. The races, rolling elements and separators are then assembled, and functional tests are performed to insure proper bearing running quality. Cleaning, lubrication and packaging are also conducted in dust free areas to insure that the final assembled bearings meet all required specifications.



5. Inspection - Because of the extremely close tolerances required, quality control plays a major role in the success of any precision bearing factory. Some factories, often at the urging of their major customers, are installing statistical process controls that 100 percent inspect parts. In other plants, roving inspectors may check a machine's output at each stage of production. In addition, machine operators have equipment to check their own work. Inspection stations are set up at each department to insure that all components passing to the next area are to specification.

### Rolling element production

The raw material for rolling elements is usually either coiled wire for cold pressing smaller diameters or bar stock for hot pressing larger (over an inch) diameters. The production process of balls differs somewhat in grinding technique from that of rollers because of their different geometries. The grinding equipment used for making balls cannot be used to make rollers. The manufacture of balls is used here to illustrate the process.

Ball manufacture can be separated into 10 specific steps.

1. Pressing - Automatic forging machines called "headers" snip off a short length of wire or slugs and press them between cup-like depressions in the dies at the rate of 400 a minute or more.
2. Flashing - The excess material, which has been left on the ball after the die impingement is then removed. The balls are fed between two file cut disks. The upper disk is kept stationary; the lower disk is allowed to rotate. The balls then roll between the plates by centrifugal force, removing the flash and nibs left by the forming die.
3. Rough Grinding - The balls are approximately .035 inch oversize prior to rough grinding. They are then fed into the grinding machine through a slot between a lower grinding wheel, which rotates clockwise at 900 rpm, and an upper driving ring moving counterclockwise at 60 rpm.
4. Multiple Groove Grinding - The balls are then subjected to successive grinding machines, each machine with a finer grinding capability. The balls enter the grinder varying about .002 inch in size and sphericity and leave with sphericity and uniformity accurate to within .001 of an inch.



5. Tumbling - After grinding, the balls are tumbled in abrasive grit and water, removing any excess material and rough spots.
6. Heat Treatment - The balls must be hardened evenly from center to surface and then tempered to give toughness. They are placed in a shaker hearth as they are fed into the furnace. The balls, being in constant motion, start at room temperature and move slowly into progressively hotter areas up to about 1,500 degrees Fahrenheit, after which they are quenched, followed by processing through tempering furnaces.
7. Precision Grinding - The balls then roll for hour after hour against the hardest kind of grinding wheel. They follow a path determined by guide plates. In about 12 hours they are true in size and sphericity to within .0001 inch.
8. Lapping - Final lapping is usually accomplished by passing the balls between one smooth plate and one grooved plate, while bathed in a special lapping compound. Variation between balls is then within .000025 inch and to even closer tolerance on bearings manufactured for bearings of ABEC5 precision or higher.
9. Inspection - Inspection is accomplished by placing the balls on a smooth surface under a bright light with a sheet of white cardboard under the balls to turn them easily. The reflection of another cardboard on the balls makes the surface defects instantly discernible.
10. Gaging - Electrolimit and air gaging sorts the balls into multiple groups, graded to size in accordance with standard (or specific) specifications.

#### Retainer production

Retainers (aka separators or cages) separate and properly space the rolling elements between the inner and outer rings. They are designed and manufactured of materials that will provide for good flexibility, yet have adequate strength to maintain designed configuration. They are not designed to carry any external load, since this is the function of the rings and rolling elements.

Retainers are constructed in several forms depending on the application and rolling element. The most common type of retainer used in single row ball bearings is the ribbon or strip design made from low carbon steel. The retainer is stamped from strip steel and then cold formed in shaped dies. The two halves are joined together by rivets, welding, or by crimping tabs or prongs. Another design is pressed metal retainers, which is a one



piece unit of low carbon steel used extensively for tapered roller bearings. The rolling element pockets are normally punched out simultaneously from steel sheet or strip by a single impact of a multiple die. This prevents undesirable distortion of the retainer. Retainers for some cylindrical roller bearings are also made this way.

Machined and cast retainers are made in either one or two pieces. They are used mostly in high speed and critically balanced applications. They can be machined from tubing stock, or cast to shape. The rolling element pockets are burnished to improve surface finish. Light weight metal alloys and non-metallic retainers are used in small, precision balanced, ball bearings. Larger bearings, such as used in gas turbine engines, are usually machined from brass, steel, or an alloyed material with high strength properties. Some small precision bearings use machined non-metallic retainers because of their low density, quiet operating characteristic, and their porous structure that acts as an oil reservoir.

#### Shields and Seals production

Shields and seals are used for two reasons: 1) to retain the lubricant inside the bearing, and 2) to keep abrasive or corrosive contamination outside the bearing. They are used primarily in grease lubricated applications, and with limited use in oil lubricated systems where protection against outside contamination is important. They may be installed on both sides of the bearing or only on one side. They are commonly stamped from low carbon steel, but are also made from a variety of other materials (such as molded rubber) tailored to specific applications.

#### Industry Performance

The bearing industry has been operating at near capacity for several years as demand continues at record levels. Despite high rates of capacity utilization, lead times for most ball and roller bearings are shorter today than ten years ago, in part because of JIT implementation. However, the commercial aerospace market has been booming for the past three years, putting a major strain on available bearing capacity serving the high-end of the market.

In the last decade, many firms in the industry invested heavily in the latest processing technologies to improve production efficiency. Productivity in the industry rose more than 45 percent in the same time period. The weakest point in the supply line is continued dependence on outside vendors for steel bar and tube stock, non-ferrous metals, and forgings. However, the problems are primarily associated with specialty and





non-ferrous metals; demand for these items is small, volatile, and hard to predict. Also, the availability of some alloying elements - cobalt, chromium, and titanium - is problematical because of their foreign origin.

The larger companies now order the more common bearing steels in smaller quantities, but more often, such as on a weekly basis instead of monthly as part on just-in-time implementation. This saves space, people, and cost. Also, quality problems with the steel are more quickly detected and corrected when they arise, saving additional dollars. Statistically, the shortened lead times at bearing plants are evidenced by the drop in the ratio of work-in-process inventories to industry shipments. This ratio fell steadily from about 40 days in 1984, to less than 23 days by 1993. (See Chart 8.) After 1993, the modest upswing to more than 25 or 26 days was related to a physical capacity constraint and tight labor markets. In 1994, capacity utilization soared to 91%, overtime hours increased, and wage levels rose above the manufacturing average by nearly 30 percent. These tight conditions persist today.

Between 1978 and 1987, the U.S. bearing industry closed more than 30 plants that were no longer competitive. Among these were about a dozen large multi-purpose plants, typically with more than 500 employees, and several with well over 1,000 employees; these had been the workhorses of the industry in a prior era. These closings eliminated about 35 percent of the industry's employment, roughly 17,000 jobs, and over \$1 billion dollars of production capacity, or nearly 25 percent of the industry's total.

The immediate and major cause of this liquidation was the severe industrial recession of the early 1980s. However, weaknesses developed in the U.S. industry's structure during the 1970's. And this, along with the growing strength of foreign suppliers, also contributed to increased imports. Because of inadequate investment, the U.S. bearing industry fell behind the major international bearing companies headquartered in Europe and Japan in implementing the latest technologies. Productivity in the industry remained largely unchanged during the 1970s. Also, concerns about bearing quality and delivery increased among bearing end-users, who were themselves faced with strong international competition.

Bearing import competition from Japan and Europe was far more severe because of the strong dollar that persisted until 1986. Imports were targeted at the biggest bearing users: the motor vehicle sector and other major bearing users such as John Deere and Caterpillar. This was very disruptive to the operations of U.S. bearing companies. However, the 40 percent drop in the dollar against major foreign currencies in 1986 caught the foreign importers by surprise, and led to very substantial dumping duties as well as record levels



of investment in new plant and equipment in the United States by both foreign and domestic companies over the following several years.

The year 1987 proved to be a watershed for the U.S. bearing industry, after which the industry's competitive position strengthened. Over \$1 billion was invested in new plant and equipment during the next four years, more than twice the normal amount. About a dozen new world class plants were opened. Bearing factories became more specialized and focused. Productivity soared to new highs. Between 1987 and 1992, roughly \$700 million in new capacity was added. Investment in new capacity was led by the foreign multi-nationals. Through this investment and acquisitions, they increased their share of U.S. bearing capacity from roughly 13 in 1981 to nearly 35 percent by the end of 1992. However, many U.S. firms also upgraded and expanded their production capacity. Exports also increased dramatically and U.S. ownership of international bearing capacity rose.

After a pause in the early 1990's, the U.S. bearing market continued growing, reaching new highs each year, and eclipsing \$5 billion by 1995. This was without inflation. A shortfall in physical bearing capacity has existed since 1993, which was filled primarily by higher levels of imports as the U.S. market expanded. The industry has also experienced very tight skilled labor markets. Although employment has increased modestly in recent years, overtime continues to be above historic averages.

### **Lead Times**

In 1987, lead times for commercial bearing customers averaged about 16 weeks and for defense orders about 26 weeks. Superprecision bearings were about double the lead time of regular precision bearings. The longest lead times for defense were reported from a year to 21 months. Lead times of 12 to 15 weeks were considered "normal" by industry spokespersons. The industry was operating at above normal capacity levels in 1986. Lengthening lead times reported by several bearing end-users led to increased imports as a stop gap measure.

Bearings are used in every factory in the United States as a production component, and/or for maintaining machinery and equipment. Extended lead times have the potential, and have on occasion, shut-down entire production lines. This can cost a customer millions of dollars in lost sales, idle his workforce, and have secondary impacts throughout the economy. During the Falklands crisis in 1982, the UK did not permit the export of superprecision bearings from an American owned Wolverhampton, England facility for



use in the U.S. produced M1A1 tank gas turbine engine. This caused the tank line to shut-down entirely for about two months.

Also, in the fall of 1985, Fafnir (closed in 1993) experienced a four month strike at its New Britain, CT facility that created turmoil in the gas turbine engine industry for main shaft and gear box superprecision bearings. The engine companies entered large numbers of add-on orders on secondary bearing suppliers which caused quoted lead times in many instances to exceed two years. The engine companies also imported greater numbers of bearings, and took steps to qualify additional foreign sources.

The bearing distribution network is extremely complex, and during almost any rapid rise in demand, lengthened lead times and supply interruptions at some point in the system are a normal consequence. The larger companies such as Timken, Torrington and SKF offer 25-30 thousand part numbers to 5-10 thousand customers that operate as many as 20 thousand bearing consuming establishments. In addition, these companies and other bearing manufacturers sell to distributors, who supply the aftermarket. Bearings, Inc. (today Applied Technologies), the largest distributor, sells about 10 thousand part numbers usually in lots of 5-10 bearings to 140,000 customers.

Bearing manufacturers generally have a core business of about 10 customers that accounts for 30 to 40 percent of their sales, and around which they schedule production. The other 60 percent of sales may be comprised of hundreds or even thousands of buyers in the case of larger production plants. A typical bearing production plant may manufacture 500 distinct part numbers, and with slight modifications, such as the addition of a dust shield or change in lubricant, may expand their offerings four-fold. If one of the core customers suddenly has a 30 percent increase in demand for his product above projected levels, the add-on bearing orders from that customer can easily disrupt the entire scheduling process and cause lead times for all customers to increase.

In a mobilization environment, the bearing industry would be inundated with thousands of new orders, as well as add-ons to existing orders which would greatly increase lead times. Initially, the greatest strains would be placed on the design and engineering, and the tool making capabilities of the bearing firms. However, the purchase of materials, including many non-standard steels, would quickly stretch out to unacceptably high levels.

In peacetime, overall, the industry is operating at near capacity, in part because of the implementation of just-in-time concepts, but also because demand is at record levels.



bearing manufacturers reported that new, or first time orders average 44.1 weeks to complete, which is 2.5 times the 17.8 weeks they reported for existing orders.

Average ball and roller bearing lead times vary over time. They also vary and fluctuate greatly by individual part number. The controlling variables include the business cycle, raw material requirements and availability, order quantity, order regularity, degree of advanced planning, difficulty of manufacture, add-ons such as special or unusual requirements, the availability of drawings, tooling, and key personnel, product stocking policy, transportation infrastructure, and incentives, such as bonuses or penalties, offered by the customer. Modern bearing establishments are more specialized by bearing type, bearing precision, and bearing size range. Specialization greatly increases efficiency by reducing machinery and equipment downtime, narrowing the number of part numbers handled, and more focused control over part quality.

Bearing Lead Time Analysis:  
New and Existing Orders

	New Orders	Existing Orders
Design and Engineering	9.1	
Materials Purchasing	12.5	
Tool Making	8.1	3.8
Production Scheduling	2.0	2.0
Queue Time	5.3	5.3
In-processing Time	5.2	5.0
Packaging and Delivery	1.6	1.7
Total	44.1	17.8

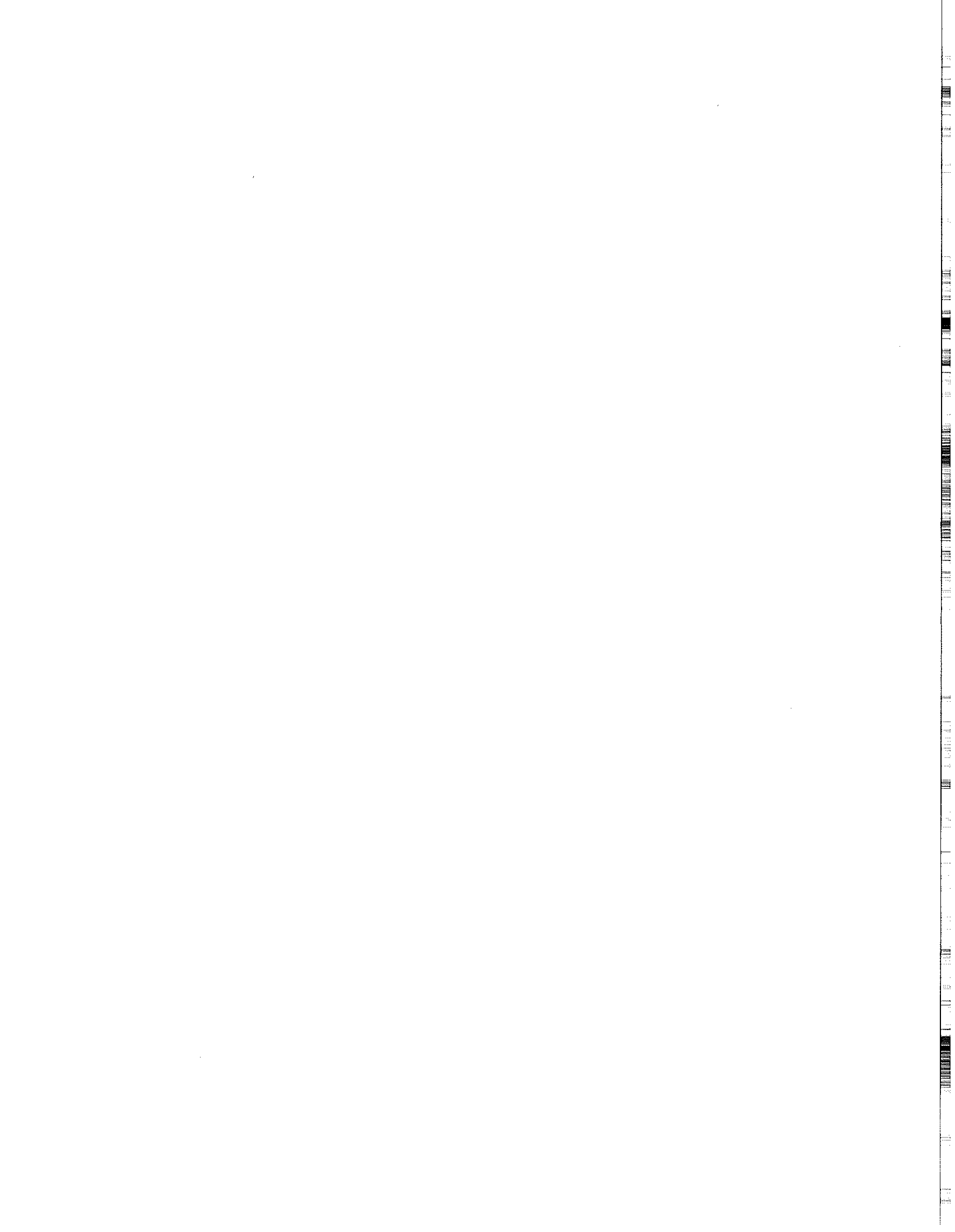
Major bearing end users, such as the auto companies and off-road vehicle firms, demanded on-time delivery, quality, and lower prices for their bearings; a top-down edict that swept through the supply chain. Most U.S. bearing firms, led by Timken and Torrington, today operate smarter and in better balance with both their customers needs and their material suppliers.





The rapid increase in the utilization of computers at every stage of production was a major factor. Computers also greatly enhanced communications with both subcontractors and customers. JIT was an influence, especially on the larger bearing companies that produce individual part numbers in large volumes for the major auto companies and others. Investment by the industry in the past decade was at record levels; as more than a dozen new plants were opened and the industry transitioned to the global economy. Since 1980, productivity in the industry rose over 80 percent.

<b>Ball and Roller Bearing Reported Lead Times: Commercial vs., Defense (in weeks)</b>			
<b>Co.</b>	<b>Company - Comments (1992 data)  Question: How can defense lead times be shortened?</b>	<b>Lead Times</b>	
		<b>Civilian</b>	<b>Defense</b>
A	By reducing or eliminating capacity utilization for commercial customers, 100% of production could be shifted to military production.	26	26
B	We are currently working on streamlining procedures.	18	18
C	Additional new equipment and skilled labor.	12	N/A
D	We experienced some additional delay in producing orders for defense because of raw material specifications, particularly for stainless steel raw material with long lead times. Lead times could be shortened by permitting us to purchase (with approval) minimum quantities of raw materials while contract details are finalized.	12	18
E	Overtime	12	12
F	By giving top priority to scheduling, we could reduce lead time to four weeks if new material is available.	8-10	10-12
G	Raw material supply	26	26
H	Increased foundry capacity	12	12
I	Shorten lead time from critical supplies by better planning and forecasting. Increase overtime in our plant.	8	8
J	Lead Time is a function of priority - not financial assistance. Lead Times can be shortened to 7-8 weeks for a few selected items. The more items, the smaller the decrease. Beyond this step, the only option is to forecast parts and move inventory closer to a shipping point.	20	20
K	Prioritize military vs., commercial orders.	14-20	16-20
L	Air freight and utilization of world-wide factory lines.	12-48	12-48
M	Overtime will enable us to shorten the lead time by 3-4 weeks.	8-10	



N	We have no new defense orders. All business is commercial.	26	
O	Access to bearing quality steel in less than 12-16 weeks and M-50 material in less than 26 weeks.	20	46
P	Use capacity to meet defense needs.	12	12
Q	Lead times for sourced components such as retainers, seals, shields, housings, springs, plastic components, etc., normally limit our ability to respond to new product orders. If our component suppliers were able to shorten development cycles, we would be able to respond more quickly also.	16-20	16-20
R	Yes, under Operation Desert Storm, we were able to deliver product in 3 to 4 weeks from receipt of order.	11-22	38

**Ball and Roller Bearing Reported Lead Times: Commercial Vs.. Defense  
(in weeks)**

Co.	Company - Comments (1992 data)  Question: How can defense lead times be shortened?	Lead Times	
		Civilian	Defense
S	Can not be shortened. (Specialized bearings requiring new setup could require up to three weeks.	1	1
T	Can be shortened to 10 weeks assuming availability of raw material.	14	24
U	1. Stockpile machined and heat treated rings. 2. Dedicate machinery to certain size and types of bearings.	30	34
V	Use of overtime; increase in inventory; priority on raw material.	22	30
W	Increase shift utilization; add new employees and establish accelerated training programs; purchase additional capacity, particularly heat treating and grinding.	16-40	18-50
X	Lead times vary greatly depending upon the specific bearing required. For non-stock items, if the necessary materials were purchased and held in stock at X Co., lead times, in many cases would be halved.	20	30
Y	Availability of equipment to expand capacity is a key factor. If capacity is not available, lead time can lengthen as much as one year.	12	

**Bearing Company Average Reported Lead Times for Superprecision Bearings in 1985 (in weeks)**

Co.	Average Lead Times		Are Lead Times Increasing?	
	Commercial	Defense	Commercial: Yes/ No	Defense: Yes/ No
A	26	26	N	N
B	36	44	N	N



C	40	60	N	N
D	26	40	Y	Y

Material lead times, non-forecasted surges do not allow time to put equipment and manpower in place, especially without long-term commitments from customers.

E	75	75	N	N
F	14 (Ball Brgs) 40-48 (Roller Brgs)	14 (Ball Brgs) 40-48 (Roller Brgs)	N	N
G	18	28	N	N
H	52	52	N	N
I	2 - 16	16 - 20	N	N
J	40 - 45	40 - 45	Y	Y

Tight capacity on bearings over 4" O.D. with special configurations. Fafnir strike increased our orders.

Co.	Leadtime Problem's Last 5Years (Y/N)	End-User Lead Time Problems Comments by Superprecision Bearing End-Users, who reported lead time problems to SIES in 1985. End-users include the several Gas Turbine Engine companies and several Gear Box suppliers.	Average lead times (in weeks) 1. Superprecision 2. Regular Precision	
			U.S.	Foreign
A	Y	Lead times exceeded quoted delivery date after receipt of order. Referral to USG Contracting Office and regular expediting at vendor's plant.	1. 40 2. 28	
B	N		1. 64	1. 48
C	Y	Variety of design, producibility, quality problems and labor work stoppages have contributed to bearing supply disruptions and delays. Generally, such interruptions are of short duration, one to three months. Sound contract administration activity, inventory control management and vendor technical support served to alleviate these situations.	1. 44-48 2. 30-36	
D	Y	Supplier was unable to deliver as scheduled. The supplier was 3 months behind schedule when he finally began shipping. This took numerous calls and visits to their plant to get that accomplished. We shipped our product behind schedule.	1. 52-60	
E	Y	To help resolve bearing shortages recently experienced by AEBG, dual sourcing has been implemented, where possible, on both mature and new engine programs.	1. 60	1. 36



F	Y	Critical shortage; expedited with executive management at manufacturer, but with less than adequate results, particularly with ABEC 1, 3 bearings (i.e., regular precision bearings).	1. 42 2. 32	
G	N		1. 65	1. 44
H	N		1. 34-60 2. 34-60	
I	Y	1. Reschedule supplier production according to Allison manufacturing priority 2. Increase production of alternate sources.	1. 48 2. 48	none

Company-> Lead time Impacts	End-Users Judgements on How Specific Actions or Circumstances Impact Lead Times (1985 Data)									Totals: Up/Down
	A	B	C	D	E	F	G	H	I	
a. Larger Order Quantities	up	none	down	up	up	none	not appl.	down	down	3/3
b. Orders at Regular Intervals	down	down	down	down	down	none	down	down	down	0/8
c. Greater complexity	up	up	up	up	up	up	up	up	up	9/0
d. Longer term contracts	up	down	down	down	down	none	down	down	none	1/6
e. Historic relationship	down	none	down	none	down	none	down	down	down	0/6
f. Other (Limited Capacity)	-	up	-	up	-	-	-	-	-	2/0

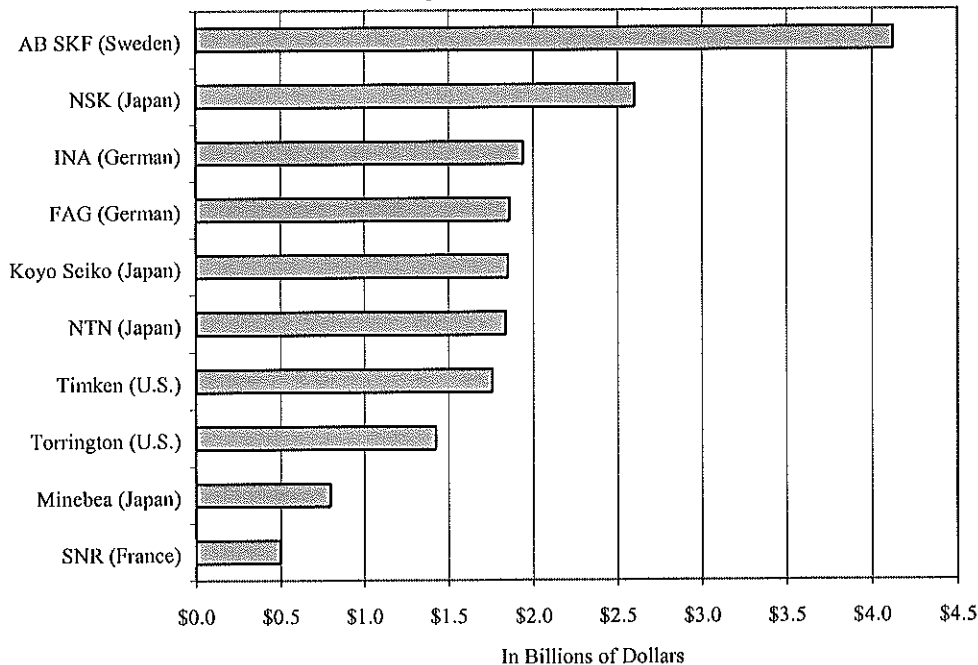
## World Overview

In 1999, the global sales of ball and roller bearings were \$23.4 billion. This was down about \$507.1 million from the 1998 sales of \$23.9 billion. These figures indicate that the largest ten bearing producers accounted for about 80 percent of the world's bearing business and that the United States bearing market represented roughly one-fourth of the world total. In 1999, the largest ten bearing firms reported \$18.7 billion in bearing sales, and U.S. consumption was \$5.8 billion. The following chart presents bearing sales by the largest ten companies.





**World's Major Bearing Companies, 1999 Sales**



### **Review of Major Bearing Company Financial Results, 1999**

AB SKF of Sweden has long been the world's largest bearing company. In 1999, SKF reported \$4.12 billion in sales, 17.3 percent of the world market. This was down about \$150 million from 1998, when SKF reported sales of \$4.27 billion. In 1998, the company lost \$186.3 million (4.4 percent of sales) despite the higher sales volume. The 3.5 percent drop in sales in 1999, however, was accompanied by a recovery in profits of nearly \$200 million. SKF achieved this result by selling off unprofitable businesses, reducing inventory, and lowering capital expenditures. The firm also benefited from the strengthening dollar, which allowed exports from Europe to the United States to realize higher prices in terms of European currencies.

The second largest bearing company in 1999 was NSK of Japan. In 1999, sales were \$2.6 billion representing a global share of about 11.1 percent. Like SKF, NSK's sales in 1999 were below 1998's total of \$2.7 billion by about \$100 million. This loss was due to two-digit declines in Japan that were partially offset by gains in exports to North America and Europe. NSK's fiscal year ended in March 1999; so about three-fourths of NSK's sales actually occurred in 1998. The Japanese economy was in severe recession in 1998, and this reduced NSK's revenues. The Yen was weak during most of this year, averaging



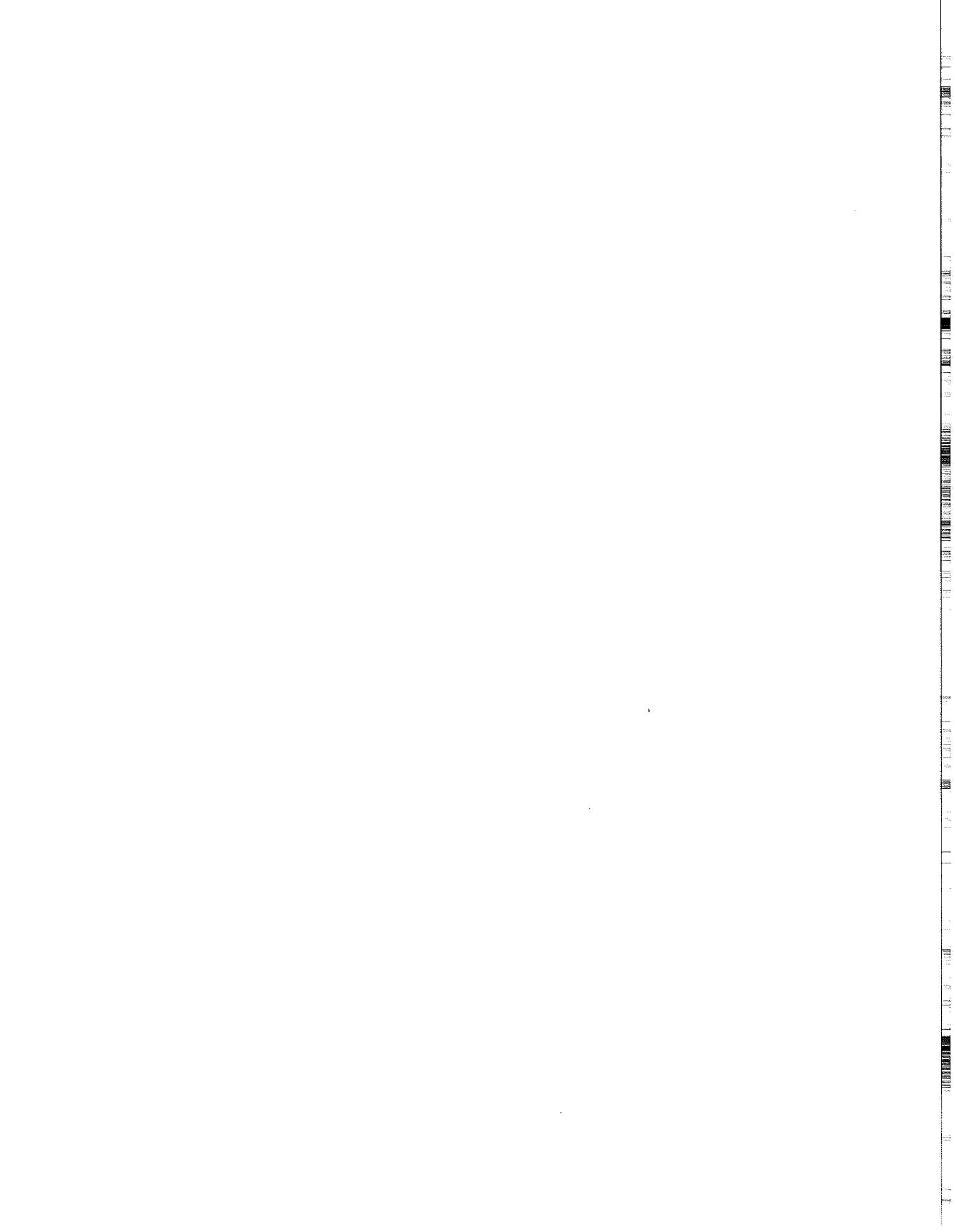
over 130 to the dollar. This encouraged exports from Japan as the company's external sales exceeded sales within Japan for the first time.

After SKF and NSK, the next five companies are rather closely matched in terms of sales; the third and the seventh company are separated by only \$180 million. INA and FAG, both German firms, are ranked numbers three and four after SKF and NSK. INA is a private firm that holds financial data very closely. Based on employment information, however, INA's 1999 sales were estimated to be \$1.94 billion, with about \$1.5 billion derived in Europe. European auto sales improved starting in the second half of 1998, and increased moderately in 1999. Most other markets remained soft. INA's focus on the auto market means that 1999 sales were probably about one or two percent more than in 1998. Sales in the U.S. market also improved. INA's increase in sales and the decreases in sales by NTN and Koyo moved INA from fifth place into the third spot.

FAG sales in 1999 were \$1.86 billion, up almost ten percent from 1998. FAG acquired a Korean company in October 1998 that contributed the lion's share to FAG's improved sales in 1999. The Korean economy grew ten percent, while FAG's bearing sales in Korea grew about 30 percent. With this spurt in sales, FAG moved from seventh place in 1998 past NTN, Koyo and Timken into fourth place. In 1999, FAG's profits were low at 2.3 percent. They were up, however, from only 1.2 percent in 1998. FAG, generally more active in the export markets than INA, also benefited from the strengthening dollar. In addition, FAG acquired a Hungarian company that helped bolster revenues in 1999.

Rounding out the top five companies is Koyo Seiko of Japan. Koyo's 1999 sales of \$1.85 billion were down almost three percent from 1998's total of \$1.91 billion. Koyo also lost money in 1999, losing \$1.2 million or -0.1 percent of sales. By comparison, 1998 profits were \$23.4 million, 1.23 percent of sales. Like NSK, the poor performing Japanese economy, which more than offset the gains in Europe and North America, afflicted Koyo. The top five companies represent 53 percent of the global bearing market.

The second five include two American companies, Timken and Torrington, which together have about a 14 percent share of the world market. The other three include two Japanese companies, NTN and Minebea, and the French firm SNR. The number six position is held by NTN. In 1999, NTN's sales were \$1.84 billion, down from \$1.96 billion in 1998. The decline was about 6.4 percent. Net profits were 2.21 percent in 1998, and 1.25 percent in 1999. Number seven Timken saw sales fall slightly from \$1.8 billion in 1998, to \$1.76 billion in 1999. While auto sales were up in 1999, they were not up enough to offset declines in the U.S. agricultural and construction machinery markets and other industrial



markets. The stronger dollar also slowed exports. Timken's net profits fell from 4.27 percent in 1998, to 2.51 percent in 1999.

Eighth ranked Torrington's sales in 1999 were \$1.43 billion; also down about one percent from 1998. Minebea, ranked number nine, had sales of \$796 million in 1999, about \$30 million below 1998's sales. Ninth ranked Minebea is the world's dominant producer of ball bearings under 22 mm in diameter and rod-ends. The firm is also the major exporter/importer of bearings to Japan, primarily from its large export platforms located in Thailand and Singapore. The Japanese recession slowed these exports. Thailand and Singapore represent Minebea's major production areas. Ranked tenth, SNR's estimated sales in 1999 were about \$500 million. Most of SNR's sales and nearly all its production are in France. Owned by Renault, SNR's sales probably advanced slightly in 1999 from the year before. The second five companies, with combined sales of \$6.3 billion, have about 27 percent of the global market. This is roughly half the share of the top five.

### Top 10 Company Profiles

The following table depicts bearing sales, after tax profits, and world market shares for the largest ten ball and roller bearing producers.

Table II.1  
World's Largest 10 Bearing Companies at a Glance

The World's Top 10 Bearing Companies at a Glance							
Company	Home Country	Corporate Year	Sales (\$Millions)	Net Profit	Market Share	Change 99/98 Sales	Exchange Rate**
AB SKF	Sweden	1999	\$4,124.2	4.82%	17.3%	-3.5%	7.54392 SEK
NSK	Japan	Mar 1999	\$2,600.6	-.87%	11.5%	-3.7%	115.202 Yen
INA	Germany	1999	\$1,941.1	N/A	8.2%	+2.0%	1.653 DM
FAG	Germany	1999	\$1,861.8	1.25%	8.1%	+9.9%	1.653 DM
Koyo Seiko	Japan	1999	\$1,851.5	2.51%	8.1%	-2.9%	115.202 Yen
Sub-Total - Top 5			\$12,379.3		53.0%		



NTN	Japan	Mar 1999	\$1,838.3	1.25%	7.6	-6.4%	115.202 Yen
Timken	USA	1999	\$1,759.9	2.28%	7.2	-2.1%	-
Torrington	USA	1999	\$1,425.0	N/A	6.6	-1.5%	-
Minebea	Japan	Mar 1999	\$795.9	3.77%	3.5	-3.6%	115.202 Yen
SNR	France	1999	\$498.2	N/A	2.0	+2.0%	5.601 FF
<b>Sub-Total - Top 10</b>			\$18,696.5	2.08%*	80.0	-2.2%*	
<b>World Total</b>			\$23,370.6				

Source: Sales and Profits: Company Annual Reports; INA, Torrington and SNR estimates based on company employment reports and other information in the public domain.

Exchange Rates: U.S. Federal Reserve (see "<http://www.bog.frb.fed.us/releases>")

\* Total profitability and sales changes compiled only from value of bearings segment reported in company annual reports. INA, Torrington, and SNR values were not available.

\*\* On an annual basis exchange rates may fluctuate 10 to 20 percent and misrepresent actual bearing production in foreign places. To arrive at more reasonable conversions, five-year average exchange rates (1995-1999) were developed and used in place of the one-year averages.

#### A. AB SKF; Goteborg, Sweden

SKF is the world's largest ball and roller bearing producer, with over \$4.12 billion in 1999 sales and 34,500 employees. Bearing sales represented 84.8 percent of the business. Established in 1907, the company has more than fifty bearing factories located in twenty countries. Over half of SKF's production base is in Europe from which the firm supplies about one-third of the European market and exports substantial quantities to points beyond, including to the United States. Major facilities are located in Germany, Italy, France, Sweden and the United Kingdom. SKF is also the fourth largest producer in the United States with five factories, and has manufacturing operations in Mexico, Argentina, and Brazil. The company has also aggressively expanded into the developing markets of China, India, Indonesia, and Eastern Europe.

SKF invested about \$85 million in bearing-related research and development (R&D) in 1999, conducted primarily at its dedicated research facility in the Netherlands. Note that this is more than the entire U.S. industry (estimated at \$70 million). SKF also owns





Ovako Steel with steel production facilities in Hofors, Sweden. SKF plans to sell its steel subsidiary in a strategy to reduce vertical integration and increase its focus on bearings. Ovako is one of the world's leading producers of bearing quality steel. The firm further processes the steel it makes with forging, rolling and turning operations in Sweden, Germany, Italy, France, the U.K., and the United States.

SKF purchased Marlin Rockwell Corporation (MRC) in Jamestown, New York in 1987 from TRW for \$35 million and proceeded to invest over \$50 million to return the operation to world-class status. The operation probably would not have survived otherwise. Today, MRC manufactures and refurbishes a full line of main shaft bearings for gas turbine engines and gearbox bearings and is a key defense supplier.

In the past thirty years SKF restructured its bearing production on an international basis. Factories that made multiple types and sizes of bearings in less than optimal quantities to supply single country markets were specialized to supply all of Europe. The European Community facilitated SKF's specialization by lowering internal tariffs and other trade barriers between member states in the 1960s and 1970s. The emergence of the Japanese companies, who entered Europe with astonishingly low bearing prices during this time, added urgency to SKF's restructuring. This had a profound impact on reshaping the world bearing industry.

## **B. NSK Ltd.; Tokyo, Japan**

NSK is the largest Japanese bearing company with worldwide bearings sales of about \$2.6 billion. Bearings represent 63.4 percent of the company's total sales. Established in 1916, NSK has been building an international presence since the early 1970's. The company's manufacturing presence in the United States is heavily focused on the auto industry. The firm has four factories, and a design and test facility in Ann Arbor, Michigan. It currently ranks number seven in the U.S. The company is not a major supplier to the U.S. Defense Department.

The company has operations in other Asian countries, Brazil and Europe. In 1990, however, NSK purchased RHP, the leading supplier of aerospace bearings in the United Kingdom. RHP produces bearings for gas turbine engines made by Rolls Royce and others. The firm is one of five in the world that makes the full range of main shaft bearings. RHP supplies the main shaft bearings for the Harrier. In 1998, NSK acquired FLT Iskra in Poland, a producer of ball bearings, and renamed it NSK Iskra.



In the last decade, NSK has also established production capabilities in China, South Korea, Indonesia, and Malaysia. NSK is a major supplier to the world's automakers; and is the second largest supplier of small ball bearings (under 30 mm) for the computer disc drive and other markets. NSK invested about \$76 million in bearing R&D. The firm is a leader in ceramic bearings.

In the year ending March 1999, NSK reported 53 percent of its bearing sales were outside Japan. While most of NSK's production capacity (about 60 percent) is located in Japan, an increasing portion is exported with a large portion of the export sales destined for the United States.

#### **C. INA Walzlager Schaeffler AG; Herzogenaurach, Germany**

INA, established in 1946, is a privately held firm with estimated 1999 bearing sales of \$1.94 billion. Bearings represent an estimated 68 percent of the company's business. The company also makes auto parts, including auto carpeting. INA employs 24,000 people overall; about 16,000 make bearings. Sixty percent of INA's workforce is concentrated in Germany and another 25 percent in other European countries. INA accounts for about 20 percent of the European market. The company specializes in needle bearings, although it produces other types as well. Needle bearings are used in transmissions, universal joints, cam followers, and other applications on motor vehicles. The company has four factories in South Carolina that also specialize in needle bearings. INA's major competitor in needle bearings is Torrington. The two companies' major production bases are located in their home countries. Direct competition is carried on within the continentally; little takes place across the ocean because of transportation penalties.

#### **D. FAG Kugelfischer Georg Schafer AG; Schweinfurt, Germany**

FAG, established in 1883, recorded sales of \$1.86 billion in 1999. Bearings represent 89 percent of the company's business. Additionally, FAG makes sewing machines and other textile handling equipment. FAG has plants in Germany, France, Italy, the United Kingdom, Portugal, Austria, Hungary, India, China, South Korea, Brazil, the United States, and Canada. FAG's Schweinfurt factory is the largest in Europe. At one time the firm employed more than 12,000 there; today, about 7,000 work in the plant. Such concentrated production requires participation in widely dispersed markets throughout Europe and beyond to keep the facility fully loaded. The company produces bearings



from about 19 mm to one meter in diameter in Schweinfurt. Schweinfurt, located in the heart of Europe, is also home to SKF's largest bearing factory that employs about 5,000 workers. It is located across the street from the FAG plant. Combined, the two facilities account for more than one-quarter of Europe's bearing production.

FAG makes military/aerospace bearings at Schweinfurt, including a full range of main shaft bearings for gas turbine engines and gearboxes. The company also makes these bearings in Stratford, Canada. A new factory dedicated to aerospace bearings was opened in Stratford in September 2000. The management plans to expand capabilities to a full range of main shaft bearing sizes from current capability of up to 14 inches, and a full line of gearbox bearings. Stratford is a key supplier to the U.S. Defense Department. In 1990, FAG also purchased the Barden Company in Danbury, Connecticut for \$190 million. Barden makes run-quiet bearings for submarines, some gearbox bearings, as well as miniature and instrument bearings for defense.

FAG nearly went bankrupt shortly after the German reunification when the Deutsche Bank raised interest rates and pushed the European economy into a severe recession. The firm dropped from 34,000 employees to about 13,000 at its low point. Since that time, FAG has recovered much of its previous stature in bearings. Today, the company ranks fourth in the world, compared to second before the crisis.

#### **E. Koyo Seiko Company, Ltd.; Osaka, Japan**

Koyo recently passed NTN to become Japan's second largest bearing company. In the year ending March 1999, Koyo reported bearing sales of \$1.88 billion. Established in 1921, today bearings represent about 61 percent of the company's total business. In addition, the firm makes vehicle steering systems, other machinery components, and a line of machine tools for the bearing industry. The auto market accounts for about 60 percent of the firm's sales. Toyota holds a 22 percent equity interest in Koyo's stock. Koyo has an R&D center in Nara, Japan and technical centers in Europe and the United States.

Koyo has manufacturing operations in Japan that account for about 70 percent of the firm's production. Koyo also has factories in the United States, Brazil, and the U.K. and in developing areas the company has production plants in China and Thailand. In 1998, Koyo acquired Romanian bearing maker S.C. Rulmenti Alexandrias S.A., which was renamed Koyo Romania S.A. Koyo's U.S. plants are in Orangeburg and in nearby Blythewood, South Carolina. Both plants are high volume operations that concentrate on



a relatively few part numbers for automotive applications. The firm makes ball bearings and tapered roller bearings at these facilities. Koyo is not a defense supplier.

#### **F. NTN Toyo Bearing Company, Ltd.; Osaka, Japan**

NTN, established in 1934, reported bearing sales of \$1.86 billion for the year ending March 1999 (only \$13 million less than Koyo). Bearings represent about 65 percent of NTN's business. In addition, the firm makes automotive components. NTN has production facilities in Japan, the United States, Canada, and Europe. NTN is the third largest bearing producer in the United States with seven factories. In 1987, NTN purchased the Bower Division from Federal Mogul with roller bearing plants in Hamilton, Alabama and Macomb, Illinois. In 1998, NTN purchased Federal Mogul's remaining two plants in Lititz, Pennsylvania and Greensburg, Indiana; Federal Mogul then exited the bearing industry. NTN also maintains a technical center in Ann Arbor, Michigan. NTN does not support the Defense Department.

NTN's Kuwana factory in Japan produces a full line of gas turbine engine and gear box bearings. The plant supports commercial General Electric engines and supplies main shaft bearings to the Japanese Defense Industry.

#### **G. The Timken Company; Canton, Ohio**

Timken is the largest U.S. bearing company. Established in 1898, Timken's 1999 worldwide bearing sales were \$1.76 billion. Bearings represent about 71 percent of Timken's business. Timken also makes steel in the Canton, Ohio area, and Latrobe, Pennsylvania. Latrobe supplies specialty steels to bearing companies in the aerospace sector. The company supplies an estimated 50 to 60 percent of the steel used in the U.S. bearing industry. Timken is the inventor of tapered roller bearings and remains the world's largest producer, representing about one-third the world's total. Timken has twelve bearing plants in the United States and a dedicated R&D facility in Canton, Ohio. Additional plants are located in Canada, the United Kingdom, France, Poland, Romania, South Africa, India, China, Singapore, and Brazil.

Timken is the largest U.S. Defense supplier, with about 20 percent of the market. Most aircraft made in North America and Europe land on Timken bearings. In 1990, Timken purchased Miniature Precision Bearing (MPB), with two key defense factories in New Hampshire. Along with MRC (see SKF), MPB makes a full range of main shaft bearings





for gas turbine engines and gearboxes at its Lebanon factory. At its Keene facility, MPB makes a full range of miniature and instrument bearings used in guidance and targeting systems. Timken allocates about \$50 million a year for R&D. About \$35 to \$40 million is focused on bearings.

## **H. The Torrington Company; Torrington, Connecticut**

Torrington, founded in 1866 as the Excelsior Company, has produced bearings for more than eighty years, and is the second largest bearing producer in the United States. In 1999, bearing sales were estimated at \$1.43 billion. Torrington became part of Ingersoll-Rand (IR) in 1968, and today represents roughly one-fourth of IR's business. Torrington has twenty-seven bearing plants and employs more than 12,000 people. Ten plants are located in the United States, mostly in the Carolinas, Georgia, and Tennessee. The company also has factories in Canada, the United Kingdom, Germany, Brazil, and China. Torrington has joint ventures with NSK in Japan and SNR in France to produce needle bearings. The company is also a minority equity partner in Industria Cusinetti of Italy, which produces spherical roller bearings.

Torrington merged with Fafnir in 1985. Fafnir had been the largest supplier of military/aerospace bearings in the United States, but was crippled by two major labor strikes in 1979 and 1985. Torrington was unable to revive this part of Fafnir's business, mostly because of declining defense sales. The aerospace operations and technical data were sold to Timken's MPB subsidiary in 1993. Torrington also sold Fafnir's former Wolverhampton (U.K.) factory to Timken in 1998. Wolverhampton makes military/aerospace bearings including smaller diameter main shaft bearings, complimenting MPB's (see Timken) U.S. operations.

Torrington has a research facility in Norcross, Georgia that was originally established to improve the bearing production process. Research and development expenditures are unknown, but probably amount to about \$30 million, or roughly two percent of sales.

## **I. NMB Minebea Company, Ltd.; Tokyo, Japan**

Minebea, established in 1951 as Nippon Miniature Bearing, is the world's largest producer of small diameter ball bearings, and represents about two-thirds of the global market (in units). Minebea is also a major factor in rod-ends and spherical plain bearings. In 1999, bearing sales were \$796 million. About 30 percent of the company's



total sales are bearings. The company also produces small motors for computer disc drives and fans, and various items for motor vehicles. Minebea constructed major export platforms for small bearings in Singapore in 1973 and Thailand in 1984 that account for nearly 75 percent of the firm's total bearing production. The Thailand plant employs nearly 7,000 people, of whom 85 percent are women in a very labor-intensive segment of the industry. The company also has operations in Europe and the United States.

Minebea's three factories in the United States operate under the name of New Hampshire Ball Bearing (NHBB); a former U.S. company which Minebea acquired in 1984. The factory in Chatsworth, California was purchased from SKF in 1971 soon after domestic sourcing requirements were added to the DFAR for miniature and instrument bearings. The other two plants, in Peterborough and Laconia, New Hampshire, came with the acquisition in 1984. Chatsworth makes small ball bearings for Defense and other applications. Peterborough makes military/aerospace bearings, including smaller sizes for main shafts and gearboxes. Laconia makes spherical plain bearings, often called rod ends used on the control surfaces of aircraft. Minebea is the fourth leading supplier to the U.S. Defense Department.

#### **J. SNR Roulements; Annecy, France**

SNR was established shortly after WW II by consolidating five factories around Annecy, France. SNR is a subsidiary of Renault, and Renault is partially owned by the French Government. In 1999, the company's sales were estimated to be about \$498 million. The company has 4,700 employees, nearly all in France. SNR has five factories in France, and three others in a joint venture with Torrington under the name Nadella (needle bearings). In addition, SNR has a minority interest in Industria Cusineti in Italy.

SNR produces main shaft bearings for the SMECMA CFM-56, the world's best selling commercial gas turbine engine and gearbox bearings. The main shaft line ranges up to about fourteen inches in outside diameter. SNR also supplies the French defense establishment.

#### **Global Bearing Market Findings**

- 1) U.S. bearing companies account for a declining share of world bearing production.** World bearing production was estimated at \$23.4 billion in 1999. The top ten companies accounted for 80 percent (\$18.7 billion). Two U.S. companies, Timken and Torrington, ranked seventh and eighth, were among the top ten,



representing about 14 percent of the total. Forty years ago the U.S. representation included six companies in the top ten (New Departure, Fafnir, Timken, Torrington, Federal Mogul, Marlin Rockwell). This was before the re-emergence of Japan and Europe in the post-World War II period.

Plagued with high labor costs, New Departure, owned by General Motors (GM), closed two of its largest factories and greatly curtailed production in a third under severe price competition from the Japanese. Currently, the company is part of the Delco family that was spun off from GM last year. Delco still makes the wheel hub bearing product line by the millions, which generates revenues of \$400 to \$500 million. Fafnir was also severely hampered by the Japanese and by high wages and militant labor. What remains of Fafnir (two plants) is now part of Torrington.

Federal Mogul gradually exited the bearing market as Japanese and domestic competition intensified during the 1980s. The firm was acquired by NTN in two acquisitions, first in 1987, second in 1998. A similar fate befell Marlin Rockwell, which allowed its operations to deteriorate. The firm was acquired by SKF in 1987.

The decline may be stabilizing. Recently, SKF sold four plants in the United States to Roller Bearing Company (RBC). In addition, some Japanese bearing capacity was shut down during that country's 1998 recession. In Europe, Georg Mueller, the fourth largest bearing company went out of business and FAG shrank more than 60 percent. FAG is making a come back. The future may be decided in the fast growth areas of China and Eastern Europe, where the large companies are staking out positions.

- 2) Bearing industry concentration levels vary by continent, but the United States is conspicuously less concentrated than its rivals.** In Europe, the top three companies (SKF, INA, and FAG) account for 75 percent of production estimated at \$6.5 billion in 1999. In Japan, the top three (NSK, Koyo, NTN) account for about 90 percent of production estimated at \$5.1 billion. In the United States, the top three, Timken, Torrington, NTN, account for 40 percent of production estimated at \$5 billion; note that one of the three is a foreign firm (NTN, Japan). This disparity made it easier for major foreign companies to capture large chunks of the American market. The major foreign companies were all caught dumping under the anti-dumping laws. Foreign owned capacity in the United States grew from about 12 percent in 1980, to nearly 40 percent in 2000.

U.S. vulnerability was rooted in:



- a) The historic tendency for U.S. firms to specialize in product types in the U.S. marketplace (e.g., Timken - Tapered Roller Bearings, Fafnir - Ball Bearings, Torrington - Needle Bearings). Each firm became proficient in their specialty, but could not offer customers a broad choice as to bearing type. In addition, they could not be a one-stop supplier to customers needing several types of bearings. Moreover, the technology and know-how synergies gained between bearing types that would be available to full-line producers, was missed by the U.S. firms. In the long run, the focus on one bearing type limited U.S. firms' potential size and left them more vulnerable to foreign companies that evolved as full-line producers.
  - b) New Departure's captive holding of large portions of the huge General Motors' market excluded other bearing companies from that market, especially in ball bearings and tapered roller bearings. In the past, GM alone may have represented from 15 to 20 percent of the U.S. market. The exclusion of other bearing companies from the GM market limited both their size and scope. New Departure also competed for business of the other car companies and in other industrial markets.
  - c) An unclear antitrust policy with uncertain guidelines made potential mergers less predictable and risky. Japan and Europe had no such constraints and quickly developed larger companies than in the United States.
  - d) American bearing companies mostly ignored developments and export opportunities in the rest of the world. Timken and Torrington are notable exceptions. In contrast to U.S. companies, the large foreign companies, especially SKF, have acquired market share through merger and acquisition, and aggressive salesmanship in the international sector. Older capacity is then retired and the work shifted to more efficient plants. This strategy was applied in the U.S. as assets were acquired, shutdown, and replaced with imported product.
- 3) North America has a large trade deficit in bearings with the rest of the world.**
- North America has a trade deficit in bearings that totals nearly \$800 million, or roughly 15 percent more than indigenous production (see tables). In contrast, the Japanese have a 30 percent surplus that amounts to nearly \$1.5 billion, and Europe has a surplus of nearly \$300 million, about five percent of production. In 1998, at the height of the Asian financial crisis, North America's deficit rose to \$925 million. The effect of these trade flows has been to reduce capacity in the United States; the most





open economy and increase capacity in the more closed economies of Japan and Europe. For the Global System to work, all players must play by the same rules.

Note that Japan severely limits imports from outsiders. Some countries in Europe (France, Germany, Italy) limit imports by favoring their own countrymen, or by creating other barriers. Their governments are historically more interventionist. When one market is down, capacity could be redeployed to other markets. Here again, the emerging markets in China, South America, and Eastern Europe are very important to future trade flows.

- 4) **Competition in the bearing industry is global in nature and very intense.** Several companies usually contest every major order. In response to end-market pressures, especially from the motor vehicle companies and other large customers, bearing producers must find lower cost solutions for their customers or risk losing market share. As a result the major companies have invested heavily in productivity, rationalization of facilities, and development of innovative products. Because of our open markets, the U.S. bearing industry, comprised now of both U.S. and foreign companies, evolved in the last 15 years as the most productive, innovative, and responsive to customers.
- 5) **Price competition rules.** High quality bearings are now the standard, and to a large extent, bearings have become commodities. Price competition has lowered economic rents and profits as companies compete to maintain market share and keep their factories fully loaded. China has depressed prices worldwide.
- 6) **Persistent overcapacity puts downward pressure on prices.** In general, prices of bearings have hardly advanced from levels of fifteen years ago. This impacts the global industry. The major reasons are related to:
  - a) Technology gains translate to higher productivity (i.e., better equipment, computerization, production cells, etc.)
  - b) Specialization of bearing plants (i.e., fewer part numbers, higher volumes, fewer set-ups)
  - c) Capacity expansion in developing nations (i.e., frequently used as export platforms, and



- d) Mounting pressures from major bearing customers to keep bearing costs as low as modern manufacturing concepts allow (Note that the customers are also confronted with overcapacity problems.)

Investments and implementation of new production technologies continually improve productivity. With very rapid scientific advances, the bearing technology cycle has been squeezed into shorter periods so that productivity has been growing faster than bearing end-markets. This puts continuous pressure on the industry to consolidate. A surplus results from both the greater production yields and the slowness of older capacity's retirement from the field. Gains in productivity lowers per unit costs, which are passed through to large and economically powerful customers. Older, obsolete equipment, now less profitable, may be shipped-off to developing countries where cheaper labor can extend its useful life.

The entry of China, for example, into world markets has not only created additional capacity, but also lowered prices of some bearings to levels not seen since the 1960s. The China factor has also cut into some of Japan's exports, thus impacting Japan's in-country capacity (as Thailand and Singapore did with small ball bearings) and the United States by lowering general price levels. Eastern Europe, India, and other areas are developing in a similar pattern.

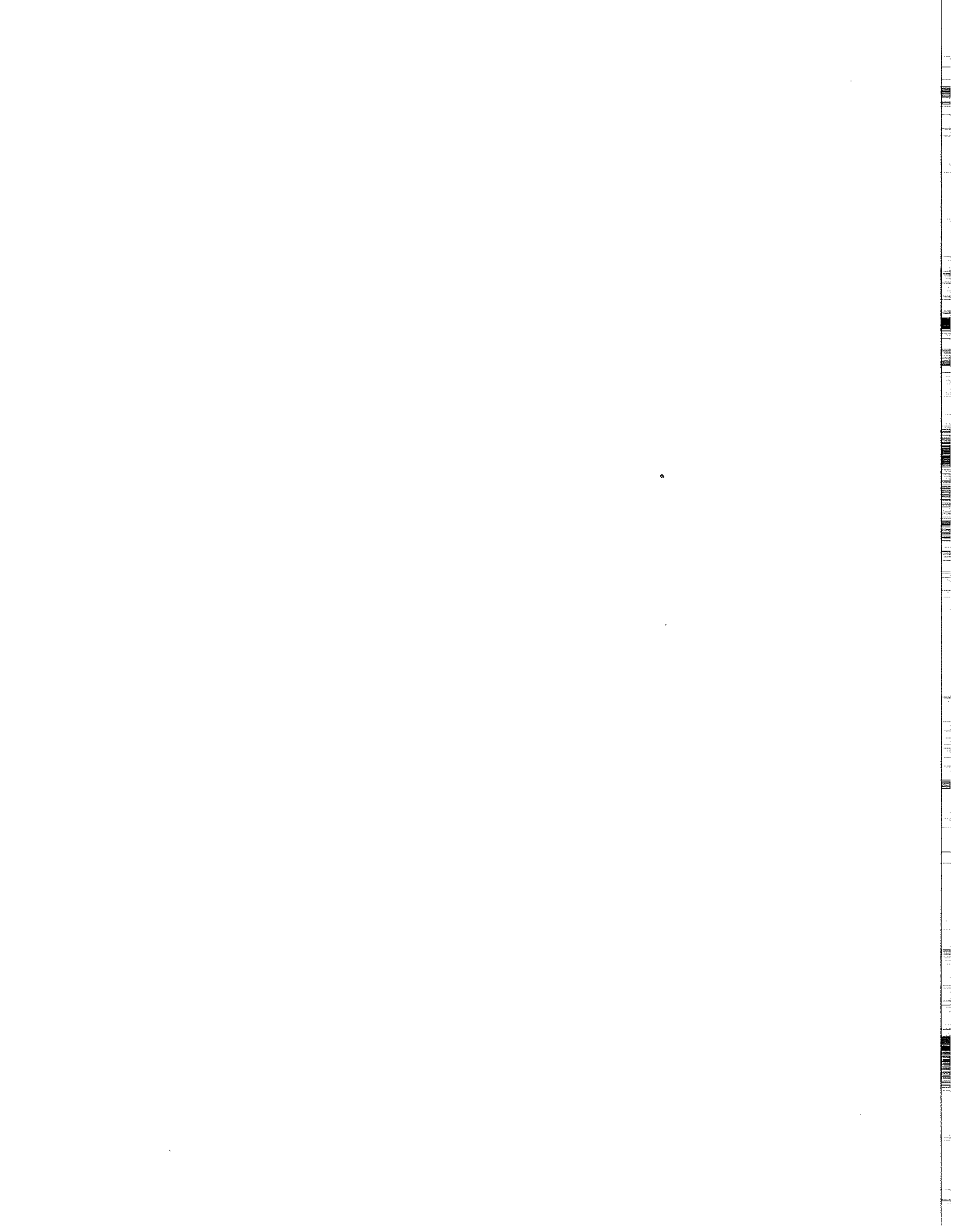
In addition, bearing materials and bearing quality have improved and extended bearing life. Longer bearing life reduces the demand for replacement bearings, and thereby, further contributes to surplus capacity. Lastly, the closed Japanese market contributes to overcapacity in slow economic times elsewhere in the world. This puts added pressure, particularly on the United States, as the Asian financial crisis attests. The North American import deficit rose from less than \$800 million to about \$925 million in 1998. When Europe suffers economic downtime, its surplus capacity is also redeployed toward the United States, partly because the Japanese market is closed to them as well. U.S. companies do not have the same opportunity.

- 7) **No bearing company has a monopoly on bearing technology or quality; however, size is a critical factor in exploiting potential gains from R&D.** The U.S. bearing industry was outspent in R&D about five or six to one by foreign firms. This could mean further losses of market share in the future. The two largest companies, SKF (\$85 million in R&D) and NSK (\$76 million), each spent more than the entire U.S. industry (\$75 million). Worldwide, about \$450-500 million was allocated to bearing related R&D in recent years.



Formal R&D spending, however, may not capture the total picture. Nearly all bearing companies tweak their machines, or bring in ideas from other industries to improve their performance. Sometimes one person can make a big difference. Today, the U.S. bearing industry imports a majority of its machine tools, which are predominantly made in Japan or Germany.

- 8) **Motor vehicle bearings account for about one-third of the world's bearing market.** The auto market is important to the top ten as their bread and butter customers, helping them leverage other markets, including defense, and R&D and investment. In 1999, 55.5 million passenger vehicles were produced, about one third of these in North America. At roughly \$150 dollars per vehicle, \$8.325 billion bearings went into this market.



## **Economic Trends: Post World War II Development of the Ball and Roller Bearing Industry**

### **World Overview**

Large companies dominate the global bearing industry. In 1996, the top 5 companies accounted for more than 58 percent of worldwide ball and roller bearing sales, and the top 10 for more than 80 percent. Two of the top 10 companies are headquartered in the United States, Timken and Torrington. Timken and Torrington together represented about 35 percent of U.S. bearing manufacturing capacity, and about 5 percent in the rest of the world. The other eight firms are also invested heavily in the United States. Combined, they comprised another 30 percent of U.S. manufacturing capacity. Outside the United States, these other eight companies accounted for roughly 80 percent of bearing production. These top ten companies and their 1996 world sales of bearings are depicted on the chart below.

Unlike SKF, the other leading bearing firms rely on home markets for the majority of their sales. These firms are only beginning to emerge as true multinationals, as they build or acquire bearing production capacity in the United States and other locations outside their home countries.

During 1991 and 1992 economic conditions in Europe and Japan were declining. SKF's 1991 sales were five percent below the previous year, while profits slipped from \$229 million (6.2 percent of sales) to only \$8.9 million (0.25 percent). FAG lost nearly \$50 million in 1991 and \$150 million in 1992. George Mueller Ball Bearing Company, Germany's third largest bearing company, went out of business. At the same time, the Japanese car market (responsible for half of that country's bearing consumption) was experiencing its worst slump since World War II. A worldwide surplus of bearing capacity has put downward pressure on prices and made the United States a bigger target for exports.

The large companies share certain characteristics. First, the worldwide motor vehicle industry is the major customer in every case, and alone may constitute more than one-third of the world demand for bearings. To supply this huge market, a bearing firm must also be large. Moreover, the characteristics of various world markets differ greatly in how they shape the bearing companies. In Japan, the auto market represents more than 50 percent of demand. Most of the vehicles are smaller than American models and rely





heavily on ball bearings. In Japan, about 70 percent of the production is ball bearings. In Europe, the auto market may be over 40 percent of the total, and again the vehicles are smaller, putting greater emphasis on the ball bearing.

In the United States, which has the most diversified industrial economy, autos may represent less than 30 percent of demand. The United States has extensive mining and petroleum equipment sectors, paper mills, agricultural equipment, construction equipment, and capital machinery and equipment industries. The U.S. also has a large transportation sector – trucks, trains, ships and boats, and aircraft – and a large defense sector. In the United States, where vehicles are larger, and the market much more diverse, greater emphasis is placed on roller bearings, which carry larger loads. Motor vehicles use other types of bearings, such as needle bearings in planetary transmissions and tapered roller bearings in differentials or in the wheels of larger vehicles.

Another common characteristic of the top 10 is high-level corporate commitment and focus on the bearing business. This appears to be very important for long-term survival, both in recognizing market dynamics and making strategic decisions in a timely manner. All of the top 10, except Torrington (a subsidiary of Ingersoll-Rand since 1968) and Nachi-Fujikoshi, are primarily bearing producers.

A lack of such commitment and focus may have hurt the American industry, especially in the last 30 years when large chunks of the American market were surrendered to international companies. In the 1950's, U.S. bearing producers dominated the world. Most have now been merged into the current top firms. Among the earlier leaders were New Departure (owned by General Motors), Fafnir, Marlin Rockwell, Federal-Mogul, Timken, and Torrington. All six were in the top 10. New Departure was gradually pushed out of non-GM markets because of high UAW wages, and in the 1980's lost the GM market as well, except for wheel hub units, which it continues to supply today. New Departure was a major supplier to Defense until 1986.

A last but important characteristic that the top ten share is their location in Japan, the United States, and Germany. These are by far the largest bearing markets and production centers. Nine of the top 10 have their largest production operations in these countries. SNR, owned partly by Renault, is the one exception. The national bearing company of France, SNR was assembled from a fragmented group of bearing companies after World War II. With a partially captive market in France, the firm may not be competitive elsewhere.



With respect to company market shares (concentration levels) in major bearing markets, it appears that company size matters. Larger size yields production efficiencies, the rationalization of facilities, wider scope, more research opportunities, and global reach. The United States has strict antitrust laws, which may have inhibited merger and acquisition activity in the U.S. bearing industry. Merger and acquisition activity is very important to the long-run competitiveness of the industry, especially in consideration of the more relaxed antitrust laws and enforcement policies in Europe and their non-existence in Japan. The bearing companies in Europe and Japan were allowed to grow in size and control major portions of their home markets. These could then be leveraged to enter other markets.

## **The U.S. Ball and Roller Bearing Industry**

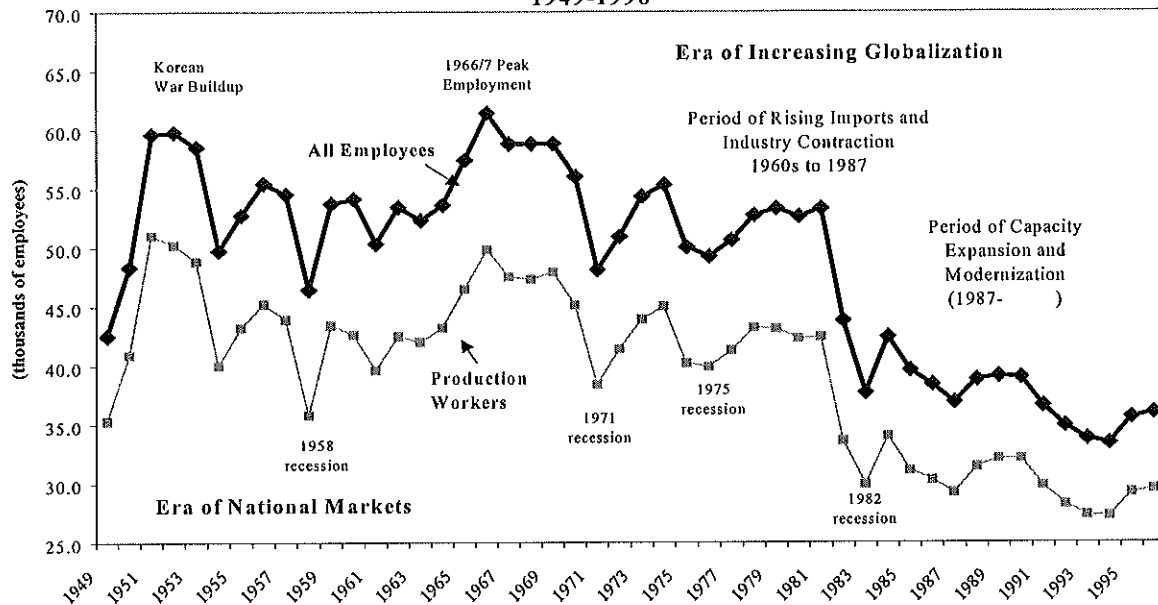
### *Employment and Productivity*

Major technical advances have occurred in the bearing industry since the end of World War II. Many of these changes can be indirectly evidenced by the long-term employment changes displayed on the chart below. Employment fluctuated wildly during the booms and busts of the period, especially prior to the early 1980's.

In the more recent period the fluctuations have been milder. Compared to today, the industry was far more labor intensive in the earlier years. In the earlier period, many more people were needed in semi- or unskilled tasks, such as material handling and assembly. These jobs have been replaced by robots, conveyor lines, real-time inspection, statistical process control, and much improved total systems layout and work flow. An increase in imported bearings that began in the 1960's, and major advances in bearing production technology gradually transformed the industry into a more capital intensive sector. This lowered the labor content, yet increased the skill requirement. Today, the skill quotient is higher, and people are not as easily hired and fired. The investment in training and knowledge almost makes the person a fixed asset. In the last 50 years, it's apparent the workforce has moved from predominantly a variable cost, to more of a fixed cost or human asset.



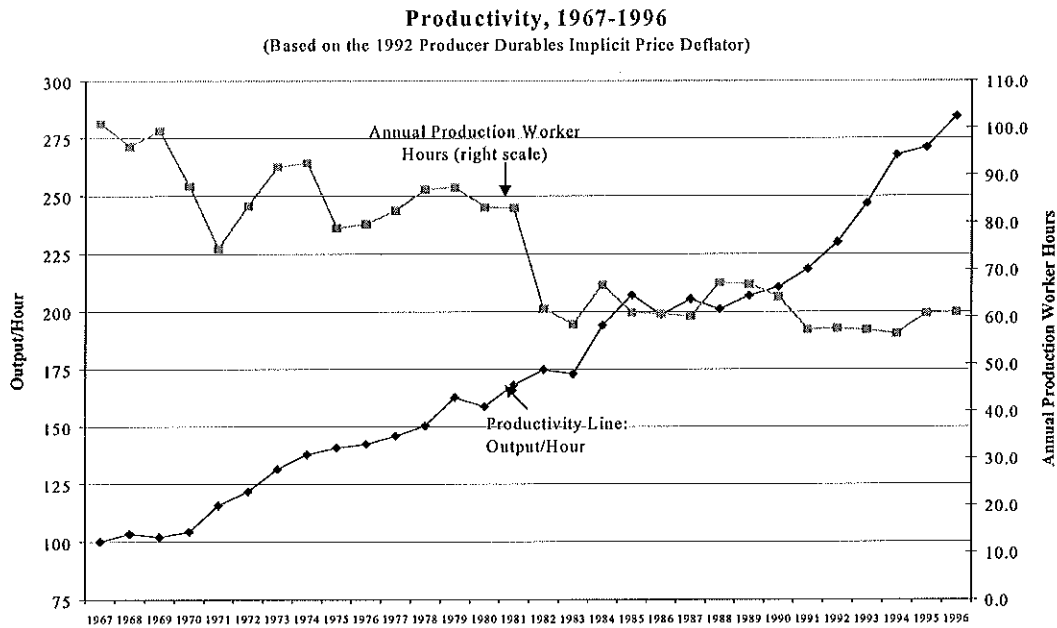
**Historic Employment in Ball and Roller Bearing Industry  
1949-1996**



Throughout the period, the total workforce averaged about 50 thousand; employment reached its post-war peak at over 61 thousand in 1966. This was related in part to the Vietnam conflict, but also to an expanding economy. From that peak, employment fell by a total of more than 40 percent by 1996, although bearing shipments grew by about two-thirds. Most of the workforce drop occurred during the steep industrial declines of the early 1980's. However, employment reached its lowest post-WWII level in 1994 at only 33.4 thousand (and 27.5 thousand production workers). Between 1994 and 1996, employment rose to 36 thousand.

Labor productivity in the ball and roller bearing industry increased about 184 percent in the last 30 years (1967-1996). This indicates an average yearly increase of 3.7 percent. If measured in five-year intervals, the average was over 20 percent. The chart shows the growth in output per production worker hour (1967 equals 100). Annual production worker hours (in millions) for the same period are also shown with a declining trend.





## Shipments

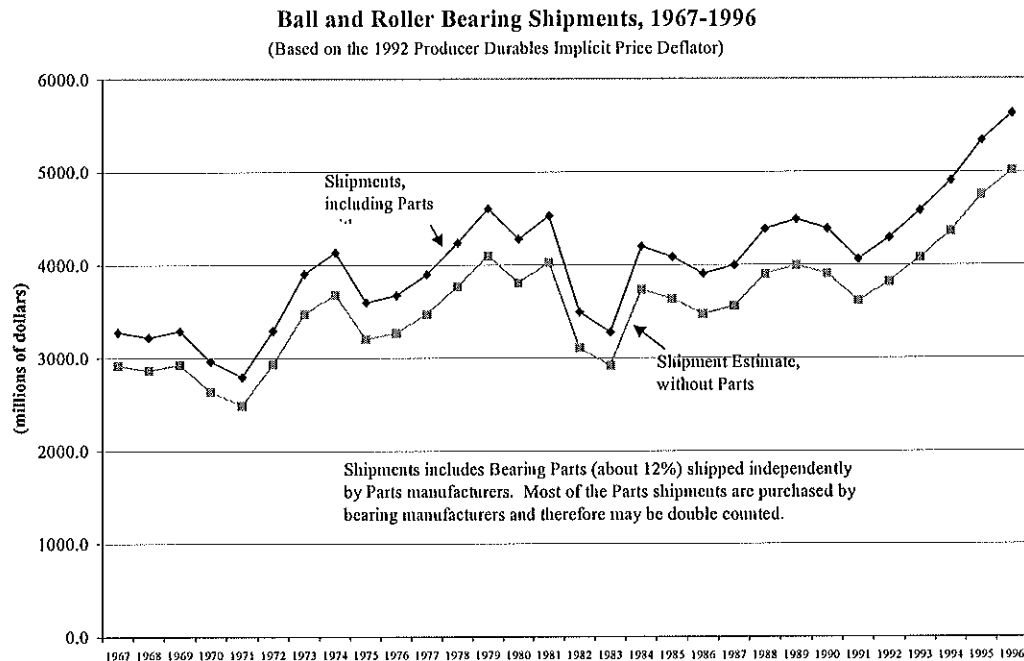
Bearing shipments showed a gradual increase from 1967 to 1996. The increase could have been higher had rapidly rising imports not been a factor. The interstate highway system and cheap gasoline created huge demands for cars that drove bearing output, and allowed bearing companies to make more efficient use of facilities through 1973. The business environment of the 1970's deteriorated. It featured floating exchange rates; a devalued dollar; two oil price explosions; double-digit inflation; runaway interest rates; rising labor costs; rising employer-paid social compensation rates; rising imports of bearings; and rising imports of the big-ticket producer durables which make up bearing end-markets and traditionally were unchallenged by foreign concerns in U.S. markets.

A very noticeable long-term trend was the migration of bearing plants to the South Atlantic states where right to work laws, lower labor cost, favorable state government policies, and a traditionally strong work ethic were and remain strong attractions. This trend began in the early 1960's, accelerating during the next 20 years, and is still occurring today. Some of the new facilities were state-of-the-art, but others, especially in the 1970's, simply moved equipment from the north and resumed production as before.





In the last decade or so, new facilities are again being constructed in the Great Lakes region.



The years following the 1979 peak in shipments began with the second oil price explosion that year, followed by a surge of smaller, more fuel-efficient motor vehicle imports from Japan. The fight against inflation created high real interest rates, raised the dollar's international exchange value, and drove the economy into its worse slump of the post-war period in the early 1980's. In 1982, domestic auto sales dipped below 6 million, the lowest level in over 30 years. Big machinery makers like International Harvester, Allis-Chalmers, John Deere, and Dresser vacated markets, closed plants and reorganized. Chrysler nearly went out of business, and American Motors closed its doors. The bearing industry's operating efficiency slid sharply in these times as average production volumes declined, plants closed, equipment lay idle, and over 30 percent of the workforce was laid off.

Also, there have been increases in the use of smaller sized bearings, especially ball, needle and tapered roller bearings brought on by structural changes in the economy and in bearing end-markets. The growth in computers and peripheral equipment; the greater use of fractional electric motors in automatic windows, seat adjusters, and windshield wipers in the auto industry; in-line skates; and home appliances, among other things, have driven an increase in the use of smaller ball bearings. The use of trans-axle transmissions and planetary gears has boosted the use of needle bearings, and quantum



improvements in steel processing have so improved the material used to make bearings that less is needed to carry the same load.

Shipments of U.S. manufactured ball and roller bearings have increased by about two-thirds measured in constant dollar values in the last 30 years. This was despite enormous import pressures, not just on bearings, but on bearing end-markets. During this period, the U.S. economy more than doubled, while the population increased from about 190 million in 1967 to roughly 270 million today.

Other trends of the last 20 years also included some positive developments. For example, the drop in bearing industry employment was more than offset by increases in productivity. Additionally, greater use is now made of just-in-time, which has greatly reduced inventory costs, and increased production efficiency. The industry has seen improvements in materials quality, machining precision, and manufacturing process controls. And, the increased use of the computer in nearly all phases of the business has improved information flow.

Between 1978 and 1987, the Commerce Department counted at least 31 bearing plant closings that totaled more than \$1 billion in capacity. Most of these plants were antiquated with high cost labor used inefficiently; at least 10 were very large with more than 500 employees. Rising imports, the deep recession of the early 1980s, and technological convalescence contributed to these closings. Since 1987, at least 10 major state-of-art greenfield plants have been opened, and many others refurbished.

There is also a marked trend toward smaller more specialized plants; in 1979, 35 plants were reported in County Business Patterns with over 500 employees (the old workhorses of the industry). By 1987 only 19 were left; some closed down while others downsized. Over the same period, plants with between 100-500 employees increased from 44 to 60. Since 1987, the situation has remained basically the same, although bearing shipments increased by well over \$1 billion. By 1995, plants over 500 employees rose to 21, while 100-500 held at 60. Plants between 20-100 employees increased from 37 to 41. The average number of employees per facility was 462 in 1978, and was below 300 the last five years (1991-1995).

ANTIFRICTION BEARING PLANTS, 20 AND MORE EMPLOYEES, 1978-1995)				
Year	# of Plants	Total Employ. (000s)	Average Plant	Number of Plants by Employment Range



			Emplo y.						
				20- 49	50- 99	100- 249	250- 499	500- 999	1000+
1978	114	52.7	462	17	20	23	22	22	10
1979	117	53.3	456	20	18	23	21	24	11
1980	120	52.6	438	23	17	21	24	27	8
1981	118	53.3	452	19	18	26	21	25	9
1982	116	43.8	378	18	21	23	22	23	9
1983	129	37.7	292	25	25	35	23	15	6
1984	113	42.4	375	16	18	27	25	21	6
1985	115	39.6	344	14	21	27	28	19	6
1986	118	38.4	325	19	15	35	26	18	5
1987	120	36.9	308	18	19	37	27	14	5
1988	121	38.8	321	21	18	31	30	16	5
1989	120	39.1	326	18	20	28	32	15	7
1990	120	39.0	325	20	21	26	29	21	3
1991	126	37.6	298	23	20	30	29	21	3
1992	127	35.6	280	25	24	29	28	18	3
1993	126	34.2	271	20	28	28	31	16	3
1994	123	33.5	272	20	23	31	31	15	3
1995	122	35.3	289	18	23	30	30	18	3

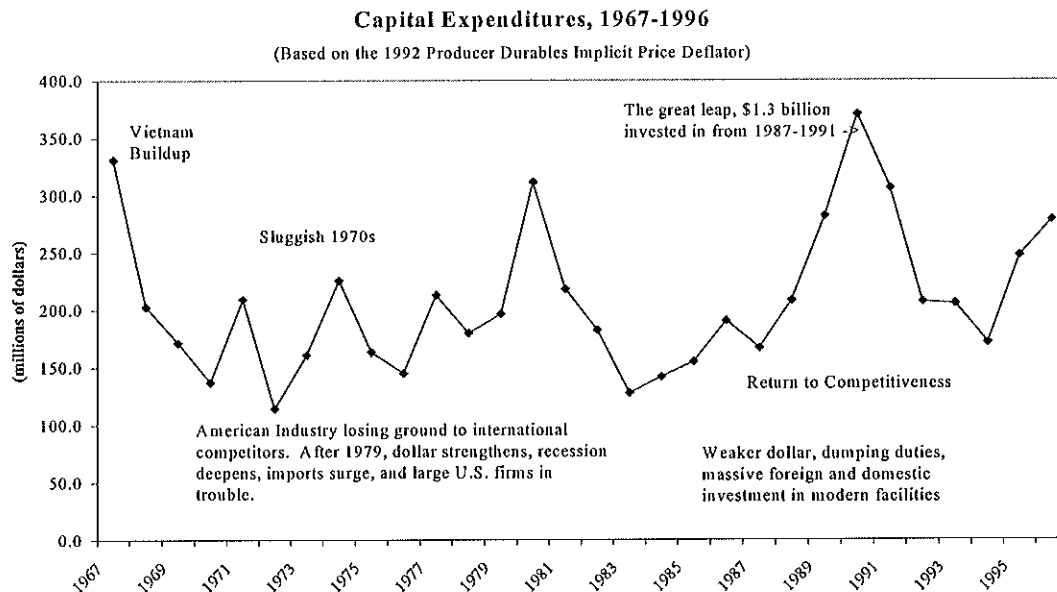
Source: U.S. Department of Commerce, Bureau of the Census, County Business Patterns, U.S. Summaries, 1978-1995

### Investment



Investment is one of the keys to competitiveness. U.S. bearing industry investment lagged somewhat in the 1970's and early 1980's before picking up rather spectacularly in the latter 1980's. This huge investment was ignited by the devaluation of the dollar on international markets in the mid-1980's. The imposition of major anti-dumping charges against the major foreign bearing firms was also an important factor, both in greatly accelerating foreign investment and providing more profits to the domestic industry with which to invest. The movement toward just-in-time, which can be better handled by local production, a surge in market demand, and finally, the need and opportunity to update facilities after the major shake-out of the previous decade also contributed.

From 1989 to 1992, \$1.1 billion was invested in just four years. Industry investment averaged nearly 12 percent of value added. In a survey by the Commerce Department, many firms were investing for the first time in CAD/CAM, flexible cells, just-in-time, and TQM. Others were introducing statistical PC, concurrent engineering, and induction heat treatments.



The machines purchased during this period are far more productive than their forebears. They are faster, sturdier, more precise, and faster and easier to set-up. They are often linked with other machines by conveyor systems, so that a bearing ring can move through the process untouched by human hands. Many machines have real-time laser measuring and monitoring devices, and computers controlling the cutting or grinding and flow of materials. Also, cubic boron nitride (CBN) grinding, while expensive, is coming into





wider use and will remove 500 times the amount of material as conventional grinding materials with the same amount of wear.

Moreover, the machines are improving in performance and productivity faster than their price is increasing. The \$1.1 billion conceals the fact that state-of-the-art machines may cost more, but also fewer machines operate longer and occupy less space for the same amount of output. They also require fewer people. So the huge investment is only a partial picture, that probably yielded far greater productivity gains than might be expected. One company put in a new plant with only 45,000 square feet and 30 employees that out-produces older plants with ten times the floor space and employees. The plant is highly specialized and focuses on high-volume wheel hub units, but it shows what is possible.

### Competitive Issues

Major short-term competitive considerations in the bearing industry are quality, on-time delivery and reliability, price, and engineering support and services. In the long term, competitiveness hinges on innovation and product development, commitment to advanced manufacturing technologies and continuous improvement, good labor relations, management commitment and focus, and good customer support.

#### Bearing Industry Workforce Compensation (1967 to 1996)

Total workforce compensation is an important element of cost. As a portion of value added, workforce compensation has demonstrated a downward trend. The graph on the following page displays total workforce compensation as a percent of value added from 1967 to 1996, and the major sub-components of compensation - *payroll*, *legal payments* such as social security, and *employer payments* made voluntarily by the employer such as medical insurance premiums.

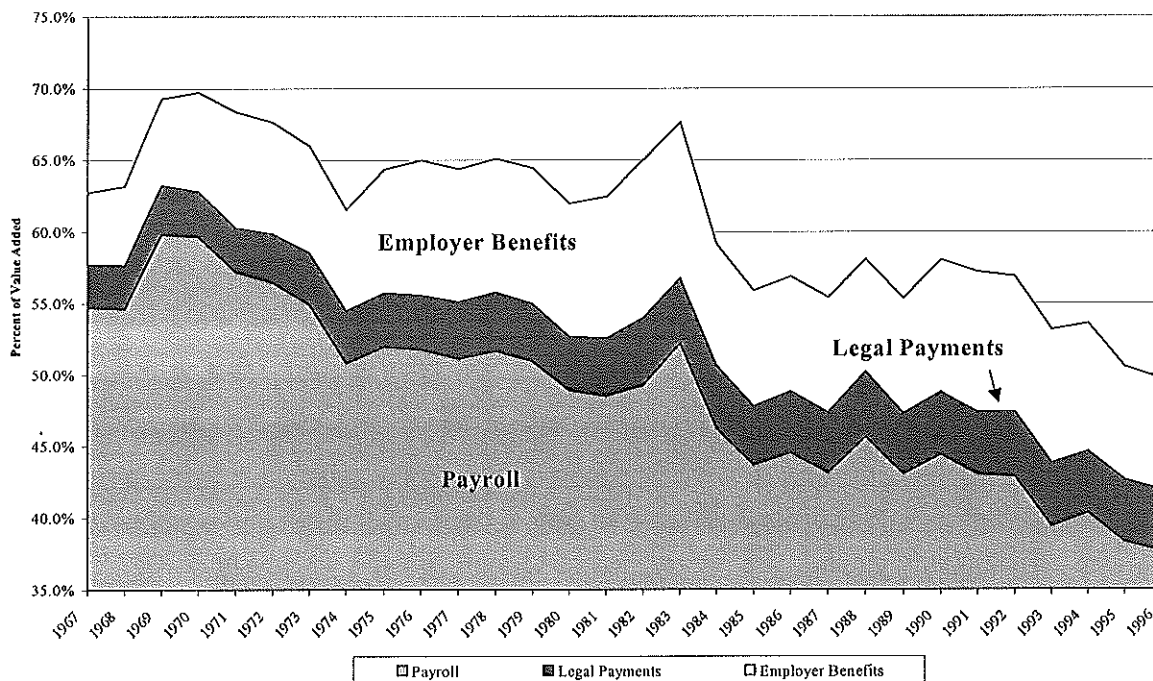
Total compensation as a percent of value added peaked at about 70 percent in 1970, fell to the mid-60 percent range during most of the 1970's (the final era of large plants), and ended at almost 68 percent in 1983. Since then, it has fallen sharply to just over 53 percent in 1993 and 1994, and to less than 50 percent by 1996. This indicates a considerable drop in total cost of labor from nearly 70 cents for each \$1 of value added in 1970 to less than 50 cents in 1996, most of which occurred after 1983.



The largest component of compensation, payroll, slipped from almost 60 percent of value added to about 39 percent over the period, while social payments climbed from 8 percent of value added in 1967, to a peak of 15.7 percent in 1982, and then eased off to just 10 percent by 1996. This was mostly because of relative reductions in voluntary employer payments.

Payroll declined steadily as a percentage of total compensation, as social payments increased. In 1967, the first year shown on the graph, payroll was over 87 percent of total compensation, but by 1996 this percentage had dropped to about 75 percent. The growing cost of labor probably contributed to the movement south and to the recent investment boom, which boosted productivity.

Workforce Compensation, 1967-1996



Total compensation or the cost of labor inputs in nominal terms to the industry was \$563.3 million in 1970, or \$10,058 per employee. It rose to \$1.405 billion in 1981, up nearly 150 percent during the inflationary 1970's, with average payments of \$26,364 per employee, and then rose to \$1.579 billion by 1994, up only 12.3 percent, while average payments per employee (note there were many fewer employees) were up almost 80 percent to \$47,260 per employee. Payroll per employee rose somewhat less. In 1970, the average payroll was \$8,607 per employee. It rose 138 percent by 1981 to \$20,477 per

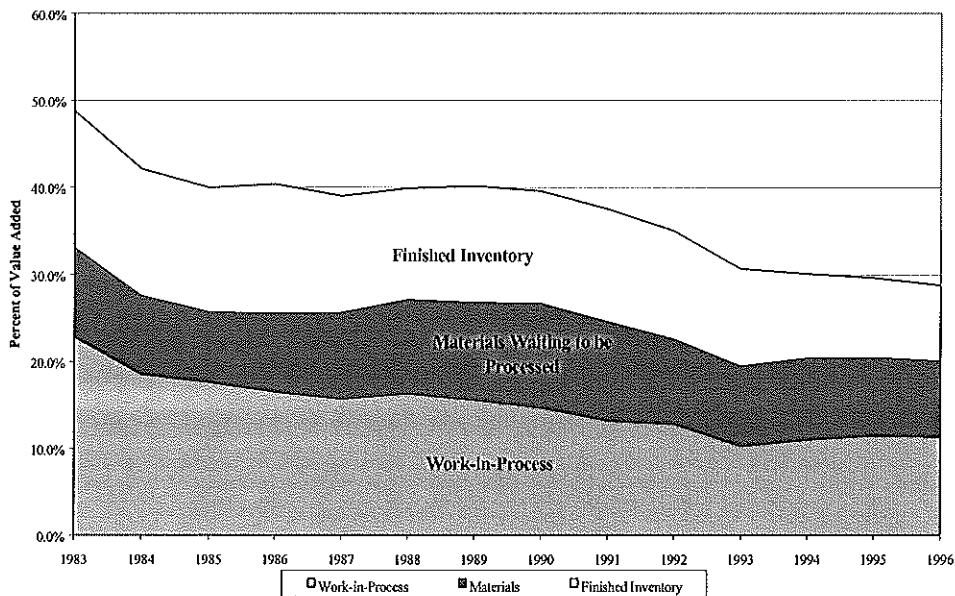


employee; and rose another 74 percent by 1994 to \$35,567 per employee. These were closely correlated to productivity increases.

#### Bearing Industry Inventory Trends (1983 to 1996)

End-of-year total inventories have declined steadily from their peak level of 48.7 percent of value added in 1983 to 28.7 percent in 1996. The bulk of these inventories were work-in-process inventory, which dropped from about half of the total to one-third of the total over the period. Work-in-process is the most labor-intensive portion of inventory. Note that it fell from about 22.8 percent to 11.3 percent of value added in a sharp downward trend. This is a definite sign of productivity improvement. This means the industry previously took an average of about 47 days to process bearings, while by 1996 it required only 21 days.

Ball and Roller Bearing Inventory, 1983-1996



Finished inventory also fell from 15.7 percent in 1983 to 8.7 percent in 1996. This may be difficult to improve further because some bearings are produced and stored in anticipation of future sales, or as a courtesy to certain customers that will need them. Material inventory has remained the around 10 percent of value added over the 1983-1996 period, although it fluctuated around 2 percent up or down. The material represents about a 50 to 100 day supply of materials, mostly steel, which is bought cheaper in quantity. Materials also represent cheaper inventory, since they are still unprocessed.



The material inventory dropped from 12 percent to 8.7 percent between 1990 and 1996, the lowest level observed over the thirteen-year period. This may be a trend downward as just-in-time works its way back to material suppliers.

#### Bearing Industry Trade Trends

The U.S. market for finished ball and roller bearings reached an all time high of \$5.54 billion in 1997. This was comprised of \$5.08 billion in U.S. manufacturer's shipments, \$1.28 billion in imports, and \$815.2 million in exports. Import penetration of the U.S. market for finished bearings was 23 percent, and the trade deficit was \$460.7 million. In terms of units, the U.S. bearing market totaled 2,274 million bearings in 1997; this was also an all time high. U.S. shipments were 1,602 million, imports 762.8 million, and exports 90.4 million bearings. Import penetration based on unit imports was 33.5 percent.

The United States had a positive trade balance from 1957 to 1971, although exports and imports were not significant. In 1971, imports were only 7.1 percent of the American market. Three years of deficits followed, then in 1975 and 1976, America had two more surpluses. After 1976, deficits have persisted to the present.

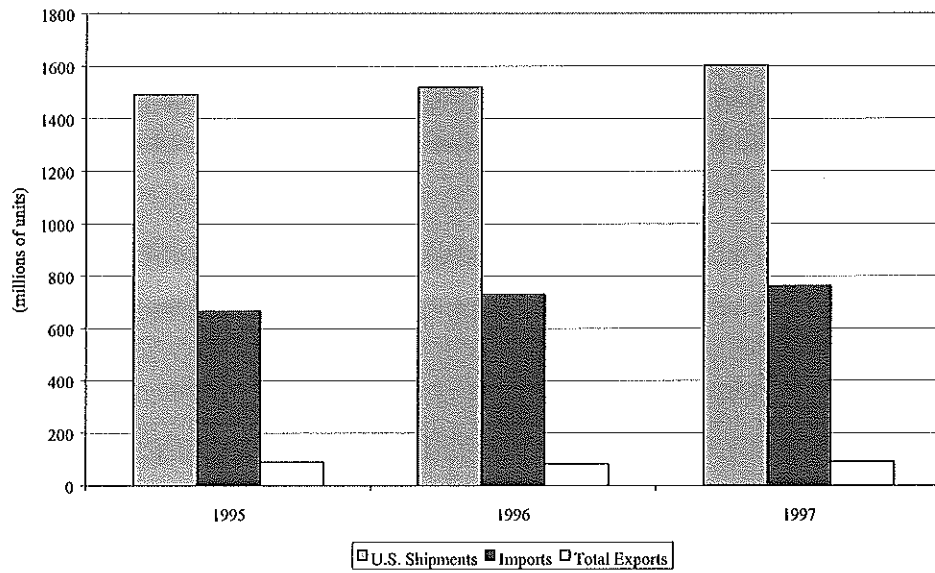
The rise in imports has been a gradual but steady process. Import penetration (in dollar terms) of the U.S. market first reached 5 percent in 1969, 10 percent in 1973, 15 percent in 1982, and 20 percent in 1988. When the dollar lost value on the international market in 1986, U.S. exports began to increase. From a low in 1986 of only \$283 million, exports climbed to over \$800 million in recent years. The import levels fell in 1990 following the imposition of anti-dumping duties, but crawled higher as China bearings, unhindered by dumping duties, soared, and Japan, with a depressed home market, sent additional quantities to the U.S. market. Large trade deficits persist with Japan, China, Germany, Canada, Singapore and Thailand.

Beginning in 1989, U.S. exports to Canada were counted by the Canadians and reported to the U.S. government for publication as U.S. exports. This explains the large surge in exports shown for 1989, and casts doubt as to the magnitude in years prior to that. Statistically, exports are of less concern because no duty is collected and they are considered beneficial. Fewer export classification numbers are in use as a result of this circumstance, and to make it easier to export in terms of paper work.

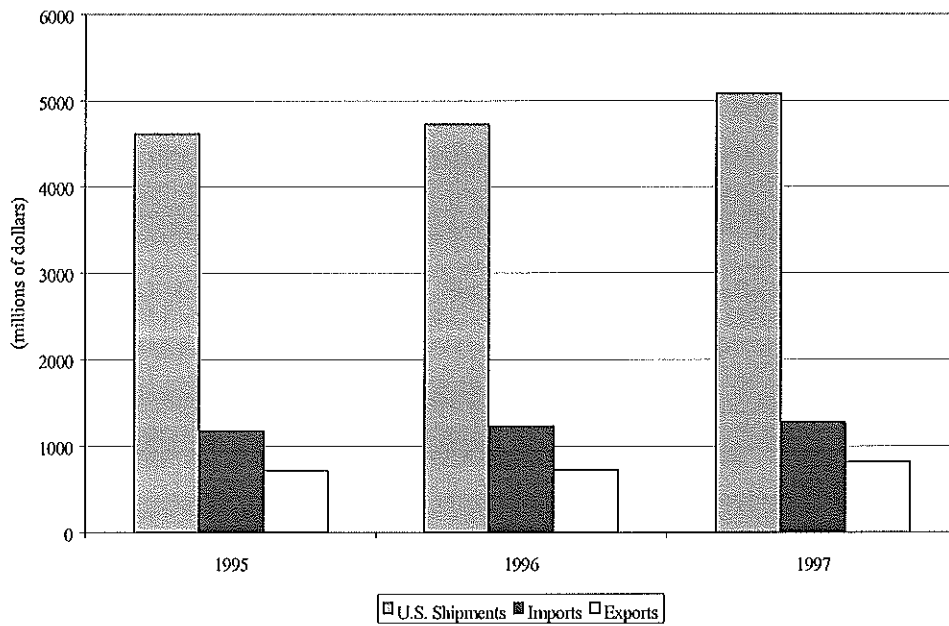


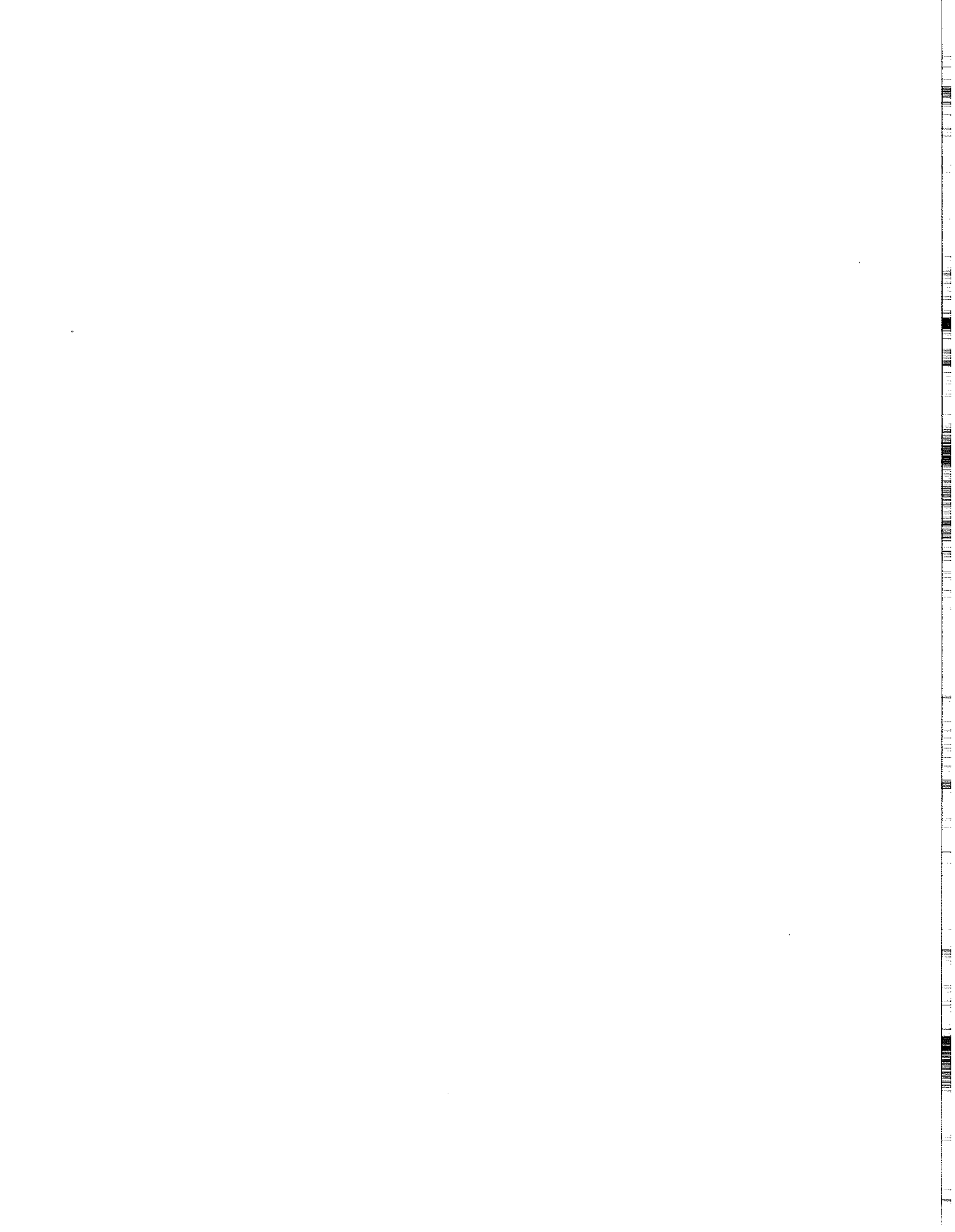


Ball and Roller Bearing Trade, Units, 1995-1997



Ball and Roller Bearing Trade, Dollars, 1995-1997





A major portion of imports are ball bearings between 9 and 52 millimeters in outside diameter. These are imported almost entirely from Japan, Singapore, China, and Thailand, although other countries such as Malaysia and Indonesia have now established production facilities. Minebea Company (Nippon Miniature Bearing) is the world's largest producer of under 30 mm ball bearings. The firm has major exporting platforms in Singapore and Thailand, and also produces in Japan and the United States under the name of New Hampshire Ball Bearing. NSK is also a major producer, with production locations in Japan, Malaysia, and Indonesia.

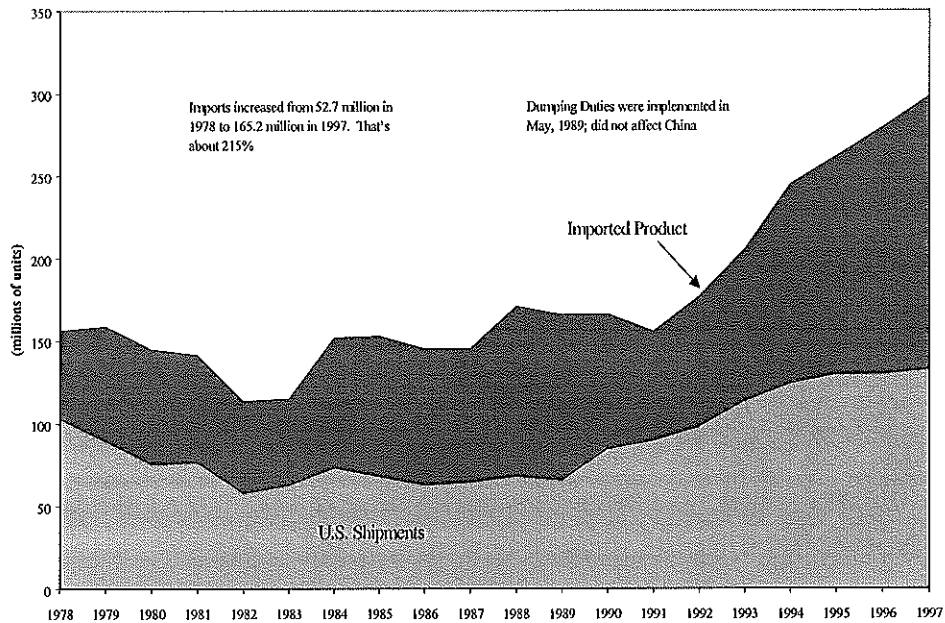
The market for small bearings is growing fast without U.S. participation. Known as miniature and instrument bearings, they are critical to Defense. They are used in gyroscopes, altimeters, range finders, and other navigational equipment found in missile guidance systems, aircraft, ships, and land vehicles. The growth markets have been computer disc drives and peripheral equipment, in-line skates, dental drills, fractional motors, windshield wiper blades, and elsewhere.

The chart shows that the market for ball bearings from 9-30 mm increased from about 150 million in 1978 to over 400 million in 1997. Import penetration was always above 50 percent, but by 1997 reached 78 percent. Imports grew from 83 to 311 million, accounting for nearly 100 percent of the growth in this product category.

The market for ball bearings in the 30-52 mm range also experienced an onslaught of imports. These were primarily from Japan and in later years, China. The bearings are used by the auto industry for under the hood applications, electric motors that run home appliances, power tools, machine tools, conveyors, escalators, fans, and pumps. They are commonly made in very large quantity, often without a particular buyer in mind.



Ball Bearings, 30-52 mm outside diameter, 1978-1997



## Defense Issues

The ball and roller bearing industry expanded more than six-fold during World War II, attaining peak production in 1944. Employment in the industry rose sharply from about 20 thousand in 1939, to more than 120 thousand by early 1944. In 1943, the War Production Board put bearings on the critical watch list because they were delaying production of aircraft engines. For a short period that year, bearings were the major bottleneck. The National Guard was called in to assist in manning the production lines. Also, women were hired in great numbers, eventually comprising about 40 percent of the workforce. Other major problems were obtaining steel, meeting the higher demand for bearings from machine tool companies, and prioritizing the deluge of military orders.

## Buy American Policy

Department of Defense, Defense Federal Acquisition Regulation (DFAR) restrictions were imposed on anti-friction or rolling bearings in two independent actions. First, on April 22, 1971, the Office of the Secretary of Defense (OSD) required that DoD purchases of miniature and instrument bearings (ball bearings less than 9 mm and 9-30



mm diameter respectively) be limited to U.S. and Canadian sources. This strategically important sub-sector of the bearing industry was very vulnerable to imported bearings from low labor cost areas, at the time Japan, and later also from Singapore and Thailand. Had this DFAR not been put in place, this subsector would almost certainly not survived. The DFAR remains in place.

In a second action, on August 4, 1988, DoD issued an interim rule that limited all other rolling bearing sizes and types to U.S. and Canadian, and "other authorized manufacture" with corporate headquarters in NATO countries. This DFAR was recommended by the Joint Logistics Commanders following a 1986 study that reported the domestic bearing industry was having competitive difficulties and weapons producers were rapidly qualifying foreign bearing suppliers. OSD disagreed on this remedy to the problem, and delayed implementation. Eventually, the U.S. Congress ordered the DFAR be implemented for an initial period of three to five years. On April 12, 1989, the interim rule was made final, but without the other authorized manufacturers clause.

The other authorized manufacturers clause stipulated that a NATO-headquartered bearing company with a U.S. subsidiary could import defense bearings up to the value of net bearing exports from the U.S. by its U.S. subsidiary. This applied to three firms: FAG, INA, and Rothe Erde, all headquartered in Germany. This excluded SKF, the largest NATO producer, who was headquartered in Sweden. SKF vehemently opposed this position as an unfair giveaway to FAG's aerospace division in Schweinfurt, Germany. The clause was rescinded.

The DFAR was established for a three-year period, with provision for a two-year extension if necessary. In September 1991, after Congressional hearings, Deputy Defense Secretary Atwood announced an extension for 15 months to the end of 1992, during which time the industry's competitive viability and the impact of the DFAR could be assessed. In the FY 1993 National Defense Authorization Act, Congress directed that the DFAR be extended for a three-year period until October 1, 1995. In the FY 1996 National Defense Authorization Act, Congress again directed that the DFAR be extended, this time for a five-year period until 2000.

The effectiveness of the 1988 DFAR bearing restriction in meeting its national security objectives depended upon the effectiveness with which it was implemented by DoD and its contracting activities. In separate audits conducted by DoD's Office of the Inspector General (IG) in 1991 and 1992, it was found that the DFAR restriction was being incompletely implemented.





These reports found that, in some cases, the procurement restrictive clause was not included in DoD contracts; in other cases, when the clause was included, contractors often did not make the required certification that bearings were domestically manufactured. Or they failed to make sufficient effort to verify that contractors actually complied with the DFAR clause. During the course of the DoD IG audits, several Army and Navy contracting units initiated immediate corrective action to include the restrictive clause in appropriate contracts. It was too soon at the time to determine whether these actions have made a significant difference in the effectiveness of DoD's implementation of the DFAR restriction.

In January 1992, DoD requested the U.S. Department of Commerce to assist in its study effort. In February 1993, Commerce issued a report documenting the business trends, capacity, the most defense critical bearings, and the impact of the DFAR's possible removal on the bearing industry.

#### Commerce Study Findings

Most bearing companies reported that the DFAR had a positive impact on their production capacity, employment, investment, R&D and profitability. In addition, the companies commented that the DFAR improved entry to defense prime contractors, increased awareness of U.S. bearing producers' capabilities, and supported U.S. maintenance of technological proficiency in superprecision bearing production. Some companies replied, however, that the effects of the DFAR were at times overshadowed by the negative impacts of defense cutbacks and the current economic downturn.

Companies reporting a negative impact were predominantly the U.S. subsidiaries of foreign-owned bearing producers. Others noted the DFAR was poorly implemented which detracted from its benefits. Companies reported that U.S. bearing industry competitiveness was also significantly affected by helpful actions such as the antidumping duties. Importantly, the DFAR helped deflect sales of imported product to the U.S. Department of Defense, which are exempt from any duty or tariff levied on imports. Thus, although delayed in its implementation, the DFAR complimented the antidumping duties at a critical juncture.

Regarding production capacity, several firms reported that the DFAR had led them to either increase or at least retain capacity that would otherwise be unavailable. A superprecision producer estimated that approximately 20 percent of its capacity increase could be attributed to the DFAR restriction. Another producer stated that the "DFAR has contributed to the retention and increased utilization of capacity that might otherwise



have been idled." Another large producer indicated that the DFAR enabled it to more economically utilize existing capacity, although the firm had not yet added additional capacity. An additional superprecision producer noted that while DoD demand for its products has decreased 50 percent over the past four years, the DFAR has enabled them to receive orders for several DoD programs which would earlier have been supplied from offshore sources.

While a superprecision bearing company reported that it hired an additional 50 workers in response to DFAR-related business, most other bearing companies responded that the DFAR had enabled them to maintain current employment, or that it had no effect on their employment level. A leading integrated producer responded that it would have laid-off half of its defense bearing work force had the DFAR not been in place. Two other large producers reported that the DFAR enabled them to stabilize their work force without requiring layoffs.

Several leading companies reported that they increased investment in response to the DFAR restriction, while others indicated that the DFAR enabled them to maintain investment at current levels despite the economic downturn. A leading producer of defense-intensive miniature bearings, for example, stated that 20 percent of its capital investment was "fueled" by the DFAR. A leading integrated producer informed us that the DFAR, combined with the coincident imposition of antidumping duties had given them renewed confidence to invest in U.S. bearing production facilities. A leading foreign-owned bearing producer reported that while the DFAR had no effect on its U.S. operations, it had made substantial investment in its Canadian facilities to comply with DFAR sourcing restrictions.

Regarding profitability, companies responded similarly that the DFAR had either increased profitability or helped offset losses during the economic downturn. Two producers replied that the DFAR enabled them to increase utilization of their equipment and thereby improve profitability by spreading fixed costs over larger production runs. Another producer complained that the impact of the DFAR on profitability has been limited due to the DoD's incomplete implementation of the restriction. Conversely, a leading foreign-owned producer reported that the DFAR had reduced its corporate-wide sales and profitability by removing business from its competitive and cost-efficient offshore facilities.

Following from the above, surveyed companies were overwhelmingly positive about the overall impact of the DFAR citing, in addition to factors noted above, improved entry to defense prime contractors, increased awareness of U.S. bearing producers' capabilities,



and support for U.S. maintenance of technological proficiency in superprecision bearing production. One foreign-owned U.S. facility further replied that the DFAR had enabled it to improve its access to U.S. Government contracts and personnel. Another leading foreign-owned producer responded, however, that the DFAR had the effect of supporting the maintenance of excess U.S. defense bearing capacity while limiting U.S. access to state-of-the-art offshore bearing technology.

#### Consequences of Elimination of DFAR

The most detrimental impact would be on superprecision bearings. DoD is the major market for superprecision bearings, accounting for over 36 percent of superprecision shipments in 1991. Firms producing regular precision bearings for defense indicated the DFAR's elimination would have a smaller impact on their firm, but could impact their defense divisions quite severely by expanding competition in a shrinking market. Direct and indirect defense requirements for all anti-friction bearings, however, currently account for about 5-10 percent of the value of bearings produced in the United States, down from close to 15 percent in the mid-1980s.

Superprecision bearing producers are already operating at low levels (63%) of capacity, as they work down defense backlogs. Opening the defense market to foreign competition at this time would contribute to the further consolidation and downsizing of capacity, and almost certainly lead to increased DoD reliance on foreign sources for these most critical bearings. From a technology as well as a competitive standpoint, the defense market plays an important and strategic role in the sector. One firm alleged that foreign competitor firms are willing to underprice U.S. Government business for access to the technology.

For example, largely due to DoD funding, superior metal alloy was developed to extend the life of bearings in the mid-1980s. This enabled superprecision bearings for the main shafts of gas turbine engines to last 3000 hours flying time, compared to only 300 to 500 hours for bearings made in the former Soviet Union. Access to this technology provides an enormous advantage in the commercial aerospace bearings sector. New business is vitally important to this sector's long-term viability and technical capabilities, and retention of the DFAR will, therefore, provide some assurance that U.S. superprecision producers will remain viable.

Regular precision bearing producers reported their defense business would probably decline or in a few cases disappear if the DFAR is eliminated. One company predicting a negative impact predicted that elimination of the DFAR could have a ripple effect as



displaced U.S. defense bearing producers begin to compete for commercial bearing business held by its competitors. One subsidiary of a diversified U.S. company complained that the DFAR's overall impact was limited by the import of products with embedded foreign-manufactured bearings. Given the formidable nature of foreign competition, elimination of the DFAR would almost certainly result in greater imports, especially in those areas where the technology has a potentially large commercial payoff.

Nearly all the defense bearing suppliers replied that declining defense expenditures have had a negative impact on their U.S. bearing operations. One small U.S. producer noted that it had stopped replacing retiring workers as government contracts had decreased by 75 percent. A superprecision manufacturer replied that it had been forced to close one of its U.S. facilities. Both a large U.S. manufacturer and a prominent smaller manufacturer responded that they had anticipated the defense downturn, and that they had been emphasizing their efforts to further penetrate commercial bearing markets. Another smaller company replied that it had increased its export efforts. Additionally, a leading foreign-owned supplier informed us that defense cutbacks will not significantly affect its business as the DFAR had already eliminated its participation in U.S. defense programs.

In summary, most companies responding believe that the DFAR had a positive impact on their capacity, employment, investment, R&D and profitability. Most companies further believe that eliminating the DFAR would have a negative impact on U.S. defense production capability and lead to greater reliance by the military on foreign sources. At the same time, many companies replied that the effects of the DFAR were in some cases overshadowed by the negative coincident impact of defense cutbacks and the 1992 economic downturn.

## Summary

### DFAR history

- ❖ As result of JLC Bearing Study (June 1986) and order by Congress, DoD implemented 3-5 year interim DFAR on antifriction bearings in August 1988; made final April 12, 1989
- ❖ Hearing called by the bearing caucus September 24, 1991 on incomplete implementation of DFAR - DFAR extended in September 1991 for 15 months by Defense Deputy Secretary Atwood to allow time for industry assessment.
- ❖ DOD requested Commerce assess the competitive status of the U.S. Bearing Industry and the need to continue the DFAR on Bearings in January 1991; Commerce reviewed 40 industry questionnaire responses representing 90 percent of 1991 industry shipments and employment: found DFAR still necessary





- ❖ DFAR extended until October 1 1995, as specified in the Defense Authorization Act of 1993;
- ❖ DFAR extended until end of FY 2000 by the Defense Authorization Act of 1996.

#### Defense Importance

- ❖ Defense requires between \$300-400 million in bearings per annum; roughly equal to 0.5 percent of Defense procurement.
- ❖ Defense requirement was \$500-600 million in mid-1980s
- ❖ About \$100-150 million in bearing procurement are superprecision bearings
- ❖ Bearings critical in aircraft, helicopters, tanks, missiles, subs, fire control equipment
- ❖ Bearings used in virtually all major weapon systems
- ❖ Bearings can be a "pacing item" in many defense applications, particularly aerospace
- ❖ Bearings present a complex logistics problem (who does what and when?)
- ❖ Bearings difficult to ramp-up or surge (labor skills, material availability, capacity constraints-heat treating, grinding)
- ❖ Bearings are key enabling technology for gas turbine engines, guidance systems, run-quiet bearings on submarines, and many other systems.

#### Trade Performance

- ❖ Shipments: \$5.1 billion in 1997, up significantly from 10 years ago
- ❖ Commercial markets up, while Defense market down
- ❖ Imports of finished bearings were \$1.28 billion in 1997, an all time high; imports of parts in 1997 were \$280 million (combined imports \$1.55 billion)
- ❖ Dumping duties on ball bearings major factor in temporary import decline in ball bearings 30-52 mm, and recovery by U.S. industry.
- ❖ Exports of finished bearings \$815 million in 1997
- ❖ Exports 16 percent of total shipments, this will probably increase as foreign economies improve; one-third to Canada and Mexico
- ❖ The value of imports was 23 percent of apparent consumption in 1997; in units, bearings were 33 percent of consumption

#### Other Performance Indicators

- ❖ Employment 36 thousand in 1996, up from 33 thousand in 1994
- ❖ Production workers 30 thousand in 1996, up from 27 thousand in 1994
- ❖ Productivity rose rapidly in last decade with introduction of new equipment and technologies; labor content in bearings down considerably
- ❖ Capital Investment a record \$1.3 billion for the five years 1988-1992; used to modernize capacity by U.S. firms, expand capacity by foreign-owned firms
- ❖ Research and development by U.S. industry has increased and was nearing \$100 million in late 1990's
- ❖ Foreign firms outspend US firms 5-to-1 on R&D



- ❖ Capacity up about 20 percent in last decade
- ❖ Total capacity about \$5 billion; utilization high
- ❖ Age of equipment: domestic-19 yrs. foreign-12 yrs (1991 reading).

Consequences of Foreign Ownership: Greater foreign sourcing

CATEGORY	(percent foreign sourced)	
	DOMESTIC	FOREIGN
❖ Machine tools	29	80
❖ Finished components	0.1	28
❖ Unfinished components	1.4	43
❖ Steel	36	61
❖ R&D	<5	>95

Major Historic Problems

- ❖ Lack of capital formation and investment incentives; greater foreign ownership may change this.
- ❖ Deterioration in bearing support sectors (machine tools, steel, labor market); have seen improvement, especially in steel
- ❖ Lack of long-term survival strategies on the part of many companies
- ❖ Too little focus on international markets; and limited access to some major markets
- ❖ Fragmentation into too many smaller firms - the need to consolidate

Long Term Trends

- ❖ Foreign firms' share of the U.S. market (including U.S. production and imports from overseas facilities) is increasing, up from 25 to 65 percent between 1980 and 1997; this will probably increase further
- ❖ Bearing end-markets (autos, machinery, aerospace, etc.) have weakened in face of international competition; this has impact on domestic bearing industry.
- ❖ Imports may decline in coming years as local content laws or desires continue to take hold.
- ❖ U.S. competitiveness increasing due to major investments by larger domestic and foreign firms locating production capacity in United States.



### Issues

1. DFAR - Should DoD endorse it
2. Dumping Duties - Sunset Provisions have exposed TRBs and Cylindrical Roller Bearings
3. Long Term Contracts desirable
4. Forecasts desirable
5. Minimum Order Quantities
6. Some bearings over engineered (stretches bearing company capabilities)
7. Capacity very lean
8. Main problem is superprecision bearings used in aerospace drive trains (gas turbine engines, gear boxes, connecting shafts)
9. Liability

