ACTIVE SOLAR SYSTEMS WITH LARGE THERMAL STORAGE FOR COMMERCIAL AND INSTITUTIONAL BUILDINGS

by Frank H. Bridgers, P.E.

Solar energy is not "free" energy as so many people have been led to believe. On the contrary, it is "capital cost intensive" and as a result, it is very difficult to justify in competition with energy conserving conventional systems for buildings. Even a passive solar system, such as Trombe Wall is capital intensive when you consider you build a glass wall you cannot see through and an 18" structural wall you do not need for structural reasons. It is probable not possible to justify any kind of solar system is competition with energy conserving systems using thermal storage for office buildings.

Thermal storage in this article refers to comparatively large 2-compartment storage tanks (approaching 1-gallon per sq. ft. of building space) where a heat pump can be used at night-time during off-peak electrical demand periods to generate sufficient chilled water and hot water to provide the heating and cooling needs for the following day, thus eliminating the need to cause additional peaking of electrical demand by operation of the cooling and heating units while lights and fans are on. In many areas of the country severe penalties are paid for pyramiding of electrical "demand" and incentives of "off peak" electrical use make thermal storage for heating and cooling a worthwhile investment. Solar energy systems in conjunction with thermal storage may have a better chance of being justified than "conventional" active solar system using the normal amount of solar storage or passive systems using heavy walls or barrels of water as storage, particularly in commercial buildings.

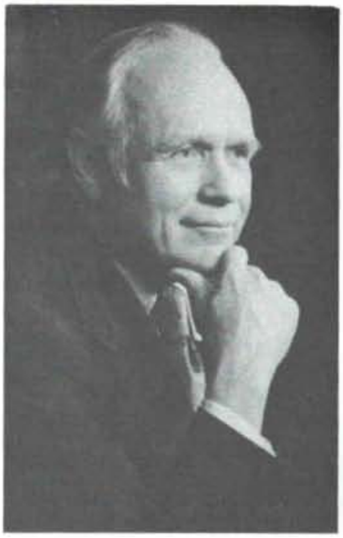
In establishing the true premium cost of solar systems over conventional systems, all cost components must be considered. The cost of the "collector" is only the beginning. Fig. No. 1 shows the total cost of different active solar systems, including solar collectors,

NOMINAL COST (Per Sq. Ft.) OF SOLAR COLLECTING SYSTEMS—1980

	Collector Cost and	Installation Plumbing	Collector Support	Storage Tank	Total
Single Cover Flat Plate (N.S.)	$12	$15	$5	$6	$38
Double Cover Flat Plate (N.S.)	$15	$15	$5	$6	$41
Double Cover Flat Plate (S.S.)	$16	$15	$5	$6	$42
High Performance:					
Vac. Tube Type	$20	$15	$5	$6	$46
Conc.-Tracking	$25	$15	$5	$6	$51

Notes: N.S. signifies Non-Selective Absorber Surface
S.S. signifies Selective Absorber Surface

Figure No. 1



Frank H. Bridgers, P.E.

Frank H. Bridgers, P.E., President of Bridgers and Paxton Consulting Engineers, Inc., received a BSME in 1944 from Auburn University and MSME in 1948 from Purdue University. He is a Registered Professional Engineer in seven (7) states. Mr. Bridgers has gained national recognition for innovative design of energy conservation systems including heat pump systems using different heat sources such as well water, internal building energy (people and lights) and solar energy applications. He was the Co-designer of Bridgers and Paxton Solar Building, the world's first solar-heated commercial building which was opened in 1956. Mr. Bridgers supervised the design of 20 other solar projects which have been funded for construction or are under construction.

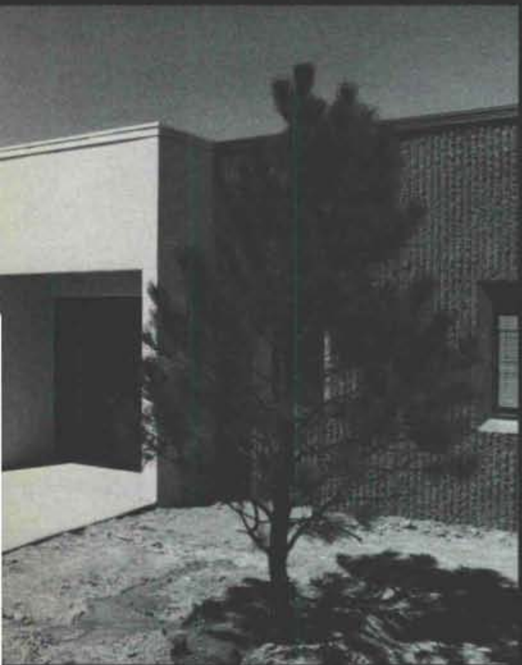
structural supports for collectors, plumbing for solar collectors and storage tank for solar system.

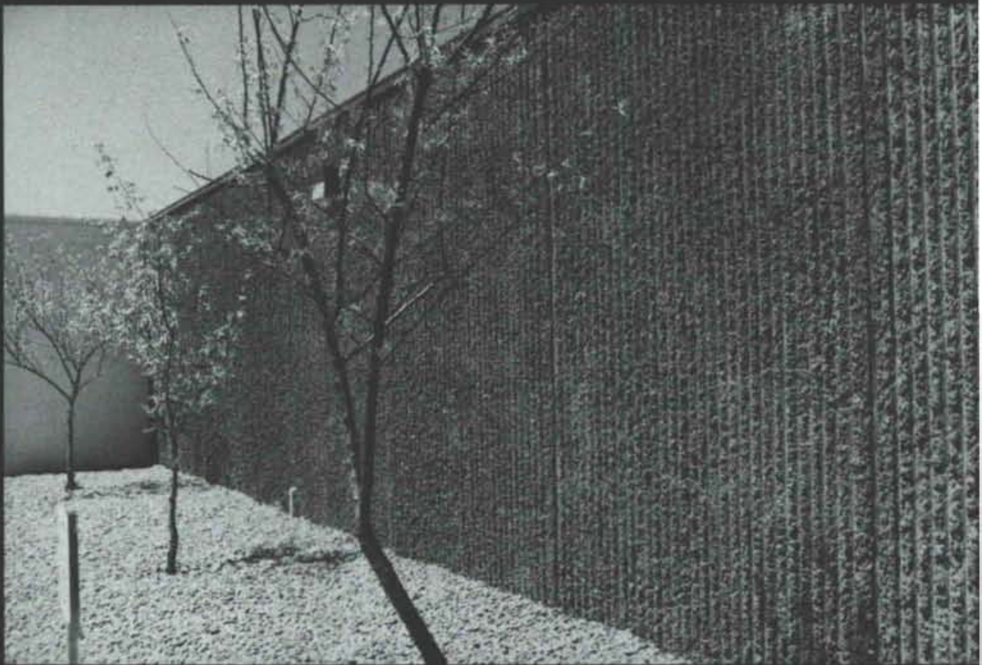
Fig. No. 2 shows the cost per Million Btu for different solar systems. The first line is a cost per Million Btu presented by a particular solar collector manufacturer showing the most idealistic possibility, assuming that all energy collected is beneficially used for a geographical location having the equivalent sunshine of 50% clear days per year. The remaining comparisons are based on computer modeling of a number of solar systems that are either operational or under construction with varying solar collector system costs and varying amount of solar energy collected and utilized per sq. ft. of collector per year. It is obvious that if ideal conditions could be attained, such as having a low cost collector system ($20 Btu/Sq. Ft.) on clear days, good percentage of sunshine (50% clear days), and all collected solar energy utilized, solar energy would be a very competitive source of energy.

The comparison of the ideal with the real world conditions is similar to the case that not many years ago was made for "on site electrical generation" for total energy systems assuming 100% utilization of "free waste heat for building HVAC systems. It didn't take us long to learn that the demand for heating and cooling and the availability of waste heat did not

Continued on page 9 ☞

Stan-Wall I-8





New from Stanley Structures, Stan-Wall I-8 . . . an energy efficient and economical wall system which is fire resistant and durable.

Stan-Wall I-8 is a prestressed/precast insulated sandwich wall panel. It has the ability to withstand stresses caused by handling, temperature and wind, as well as roof and floor loads.

Stan-Wall I-8 provides you with an attractive, sculptured exterior finish and a smooth interior wall surface.

Consider Stan-Wall I-8 for your next building project as an economical way to achieve an architecturally pleasing look with considerable savings in energy, maintenance and insurance costs.

To help you tailor Stan-Wall I-8 to your design needs, or for additional information on cost and details, contact one of Stanley Structures' sales representatives.

Stan-Wall I-8 panels from Stanley Structures offer these benefits.

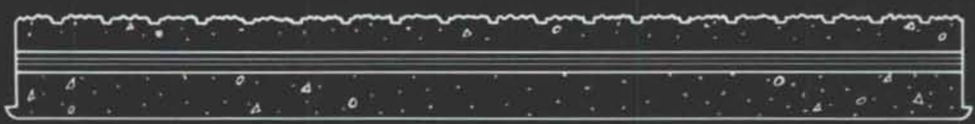
☐ Our Stan-Wall I-8 sculptured exterior surface is manufactured in a tasteful, modern design. Panels are 8 feet wide with thicknesses of 8, 10, or 12 inches with varying heights according to your design requirements.

☐ A layer of quality foam assures even insulation over the panel's entire surface.

☐ The layer of insulation is sandwiched between two prestressed concrete panels, forming a resilient wall that flexes without cracking.

☐ Compatible with any framing system.

☐ The hard interior surface forms a functional wall that resists damage from forklifts or other handling equipment.



Stanley Structures

2340 Alamo Southeast
Suite 106
Albuquerque, New Mexico 87106
Phone 505-247-0391

(Frank Bridgers continued from page 7)
necessarily coincide, and that most of the "free" waste heat had to be dissipated to the atmosphere.

COST PER MILLION BTU PER YEAR FOR SOLAR (INTEREST AND PUMPING COST NOT CONSIDERED)

Cost Range Solar Collecting Systems	Average Btu Collected Per Sq. Ft./Year	20 Yr. Life	30 Yr. Life
$20/Sq. Ft.*	365,000*	$2.73	$1.83
$25/Sq. Ft.**	142,000	$8.80	$5.90
$40/Sq. Ft.**	150,000	$13.33	$8.93
$45/Sq. Ft.**	165,000	$13.64	$9.14
$50/Sq. Ft.**	180,000	$13.88	$9.29

*Theoretical data given by Manufacturer for 2000 Btu/day, 50% clear.

**Data based on computer simulation for projects that have been bid.

Electric Resistance @ $0.05 per KWH

$$\text{Cost per Million Btu} = \frac{1{,}000{,}000 \text{ Btu} \times \$.05/\text{KWH}}{3413 \text{ Btu/KWH} \times 1.0 \text{ C.O.P.}} = \$14.64$$

Electric w/Heat Pump @ $.05/KWH

$$\text{Cost per Million Btu} = \frac{1{,}000{,}000 \text{ Btu} \times \$.05/\text{KWH}}{3413 \text{ Btu/KWH} \times 4.5 \text{ C.O.P.}} = \$3.25$$

Natural Gas Cost @ $2.50 per MCF

$$\text{Cost per Million Btu} = \frac{1{,}000{,}000 \text{ Btu} \times \$2.50}{1 \text{ MCF} \times .70 \text{ Eff.}} = \$3.57$$

No. 2 Oil Cost @ $0.90/Gallon

$$\text{Cost per Million Btu} = \frac{1{,}000{,}000 \text{ Btu} \times \$0.90}{120{,}000 \times 0.70} = \$10.71$$

Figure No. 2

A similar situation occurs for many systems. The conventional solar system has the storage designed for a 4 to 8 gallons of storage per sq. ft. of collector. This does not allow retainage of all solar energy collected until it is required by the heating or cooling system and, as shown on Fig. No. 2, the actual amount of heat that can be collected and utilized is less than half the idealistic values.

An examination of Figs. No. 1 and No. 2 would indicate two important requirements to make solar systems more economically feasible:

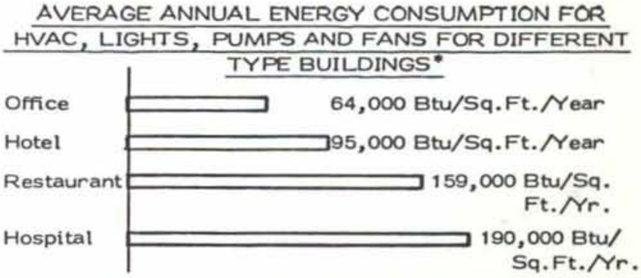
1. Increase the utilization of the solar energy collected.

2. Lower the premium cost of the solar collector system.

In this article we will show that thermal storage systems can contribute to both of the above requirements, along with some other important considerations.

Mr. Robert Tamblyn and his associates of Toronto have convinced many engineers that for office buildings, using sound energy conservation principles and thermal storage systems, that you almost get the last "squeal out of the pig" and there is very little HVAC energy requirements left to be saved by using solar energy. If you can't save a significant amount of energy with solar energy, you certainly can't afford the high capital of the solar system.

Therefore, it is obvious that we must look to other types of buildings that require considerable more annual energy consumption than office buildings to obtain a greater utilization of solar energy. Fig. No. 3 shows a comparison of energy consumption for office buildings with hotels, restaurants and hospitals. These



*Final Report January 1978, Phase One/Base Data for the Development of Energy Performance Standards for New Buildings, U.S. Department of Housing and Urban Development

Figure No. 3

comparative annual energy requirements do not include domestic hot water heating which would increase the differential in energy consumption shown by an additional significant percentage. Another important difference is that the lighting level and the percent of energy contributed by the lighting system is considerably less for hotels, restaurants and hospitals than for office buildings. The lower lighting give less internal heat source for the heat pump system.

You might ask—"What does this have to do with thermal storage?" The answer is that with greater year around energy requirements and a storage system sized to take advantage of night-time storage of energy, a larger percentage of available solar energy can be utilized. This increases the Btu/Sq. Ft./ Year of solar energy utilized for the solar collector and approaches the idealized condition shown in Fig. No. 2, thus lowering the cost per Million Btu. This would help satisfy the first of the two requirements mentioned previously that would make solar energy more economically feasible.

The second condition is to reduce the cost of the complete solar system. If the plumbing and installation cost can be reduced by shipping collector systems that have a maximum amount of factory pre-assembly and pre-piping, the field labor cost can be significantly reduced. The nominal size of most modular flat plate collector panels is approximately 6 ft. X 3 ft. For field installation, two plumbing connections and manual handling and placement of each 18 sq. ft. of collector are required.

To overcome the large amount of field labor and reduce the plumbing cost, the fabrication of large preassembled modules with provisions for internal headers so that several modules can be connected in series has been used on solar projects such as the Denver Community College as shown in Fig. No. 4. Collectors having a module size of 20 ft. X 3 Ft. with internal headers that allow easily coupling of from 3 to 6 modules in series can significantly reduce the field labor and therefore, the total cost of the solar collector system.

Another way to improve the economics is to make dual use of the solar collector panels. Solar collector modules can be arranged to shade south glass in the summer and allow passive solar energy collection in winter. This scheme was a part of the design for the Program Support Facility for the Argonne National Laboratory, one of the award winners of the 1979 Owens-Corning Energy Conservation Awards Program. For the summer cooling season, this can provide a shading factor that might cost $33 to $5 per sq. ft. of glass for heat absorbing or reflecting glass and not allow as efficient passive energy collection in winter time.

If the cost of the storage system could be eliminated that would normally be charged to premium cost of the solar system, the economics of the solar system would be improved. It has been shown by Tamblyn and others the entire cost of the thermal storage system is economically justified due to savings in electrical energy demand cost and refrigeration capacity initial cost.

The total credit that could possibly be allowed for a solar system with a properly justified thermal storage system on a building having an energy consumption requirement of over 120,000 Btu/Sq. Ft./ Year might be as much as indicated below:

Credit for Storage	$ 6.00
Credit for Large Modules, Installation and Plumbing	$ 7.00
Credit for Shading South Glass	$ 3.00
Total Possible Credit	$16.00

A system that would normally have to be justified for a cost of $50 per sq. ft. of collector could be computed on $35/sq. ft. premium and 200,000 Btu per sq. ft. collector per year, which would give a 30-year energy cost of $7.00/Million Btu as compared to $9.29 per Million Btu without such credits. An energy cost of $7.00 per Million Btu could be justified against electric resistance heating with energy cost above 2-½ cents per KWH not considering interest. *F.H.B.*

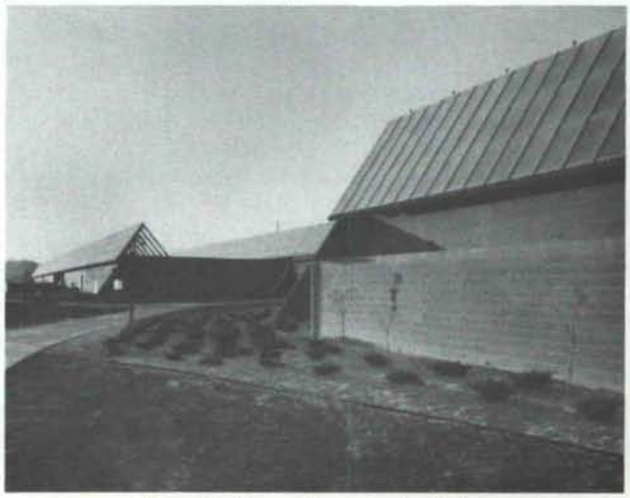


Figure 4. Denver Community College


CENTURA
PULL ON
PUSH OFF
KOHLER
WASHERLESS FAUCETS IN THE KOHLER TRADITION


PUSH
OFF
PULL

entura.™ Single control aucets from Kohler Co.

tyling that's elegant, a **washerless"** cartridge that's ependable, and Water-Guard ater-saving flow control for avatory and sink faucets with erators put Centura faucets in a lass above the rest.

Vith Centura, Kohler offers a hoice of single lever or push-ull lavatory and sink faucets nd an elegant push-pull ath/shower control.

dd to that a choice of nishes — 24 carat gold elec-roplate for push-pull lavatory aucets and bath/shower con-ols, and gleaming chromium or lavatory and kitchen sink aucets and bath/shower con-ols.

n the inside, Centura features a asherless cartridge you can de-end on for long-lasting service nd no-leak, no-drip water con-ol.

entura — all the beauty, conve-ience, selection and depen-ability anyone could ask for in faucet line.

ictured at left: Centura push-ull Water-Guard lavatory aucet in 24 carat gold elec-oplate. A touch of richness for ny bath or powder room. With old, cleanly sculptured lines nd lustrous finish. K-6882.

Single Lever Centura Water-Guard lavatory faucets offer fingertip operation and easy, positive selection of water temperature and water volume. One hand controls the faucet for the utmost in convenience. Shroud is made of high impact corrosion-resistant A.B.S., a material that offers longer life and less corrosion than faucet parts made of zinc. Centura single lever lavatory faucet available in chromium only. K-6883.

Sink Faucets in the Centura line offer a pleasing combination of beauty, practicality and Kohler's Water-Guard water-saving flow control.

Chromium finish retains lustre with a minimum of care. One-hand controls water flow and temperature. Handles rotate a full 180 degrees for maximum control of water temperature; no inconvenient temperature variations caused by minute handle movements. Washerless cartridge is designed to help conserve water. Positive water shutoff remains at the predetermined temperature; cartridge does not return to an inconvenient neutral setting when faucet is shut off. Nine-inch swing spout puts water over the work area of the sink. Celcon bearings on spout posts insure smooth operation and extended no-leak, no-drip dependability.

Centura Water-Guard sink faucets are offered in your choice of single lever or push-pull control.

Centura simplifies back-to-back lavatory, kitchen sink and bath/shower installations. Hot and cold supplies can enter either side of the faucet. In installations where the supplies are reversed, the valve stem can be rotated 180 degrees to compensate for the reversal. Saves time and money.

Centura push-pull faucets and bath/shower controls offer smart styling for bath, powder room or kitchen. Sparkling acrylic handles are easy to grip, easy to control. You dial the exact temperature you desire — left for warm-hot, right for cool-cold. Easy up-down or in-out movement controls water volume at the same time.

Elegant Centura tub/shower ensemble in gleaming chromium features push-pull mixing valve that provides water volume and temperature selection with one easy movement. Sparkling acrylic handle and handsome dial plate add beauty to the bath. Also available in 24 carat gold electroplate. K-6872.

NTROL

ntura single control faucets and bath/shower ntrols have comfort zones that are five times der than most other single control faucets. You ntrol water temperatures easily; you don't have get chilled or burned before you get comfor-ble. And that's especially important in th/shower controls. An ingenious tapered cam s you turn the handle a full 180°. So you set e temperature exactly where you want it. Cen-ra. It puts control right where it belongs. Right your hands.

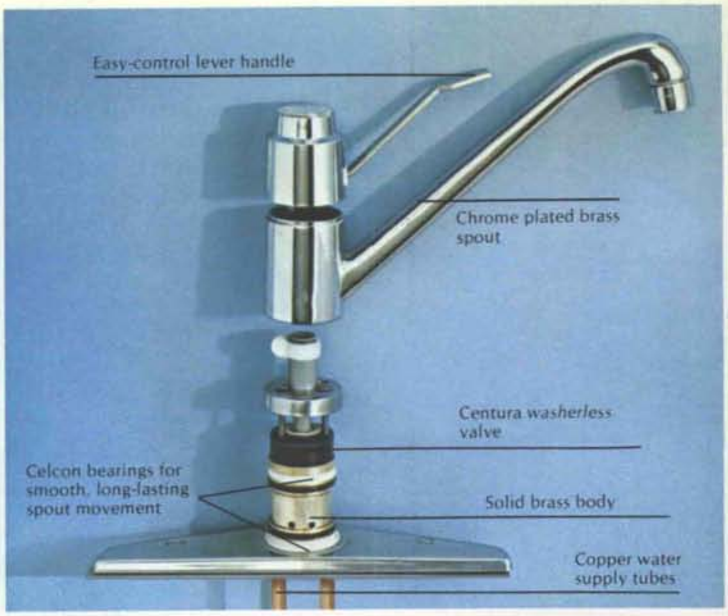
Centura lets you enjoy a comfort zone five times wider than most.

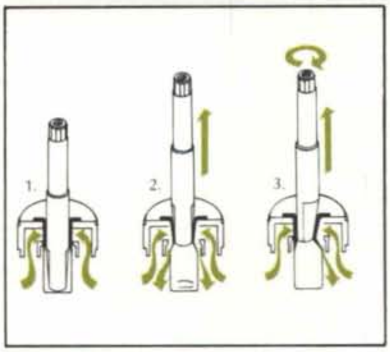
CENTURA

Kohler Centura single control faucets work as well as they look. They will serve you better, longer than other single control faucets. . .thanks to a dependable, washerless cartridge combined with thorough Kohler engineering and craftsmanship.

Compare these Centura features and you'll see why:

- **Centura cartridge has no washers, O-rings or springs — parts that can cause leaks in ordinary faucets;**
- **Washerless cartridge is self-contained, non-metallic and corrosion-resistant;**
- **Washerless cartridge has only one moving part. . .and that part is permanently lubricated and completely isolated from the water so that it is not affected by adverse water conditions — sand, silt, akalines, etc.;**
- **Internal parts — other than the cartridge — are made of long-lasting, corrosion-resistant brass that is precision machined to fine tolerances;**
- **Handle rotates 180 degrees for maximum water temperature control, and "lifts" more than one inch for maximum control of water volume;**
- **Smooth opening and closing. . .eliminates sudden bursts of water that can splash out of the bowl;**
- **Copper inlet tubes are securely attached and brazed to body to prevent leakage;**
- **Centura shrouds are made of non-corrosive plated ABS, and stainless steel for long-lasting durability and easy-care beauty;**
- **All Centura lavatory and sink faucets with aerators offer Kohler's Water-Guard water-saving flow control at no additional cost to help lower water bills and water heating costs;**
- **Autel Water-Guard showerhead offered with Centura bath/shower features maximum 3 GPM flow control and Delrin face to resist build-up of clogging, corrosive salts;**
- **Centura offers push-pull and single lever controls for consumer preference and convenience.**





Kohler's Centura washerless cartridge is designed with built-in dependability. It has only one moving part. And that part is permanently lubricated and completely isolated from water.

Water conditions such as alkalinity, sediment or high iron content will not cause the Centura cartridge to deteriorate or leak because water does not come in contact with the control cam.

Illustrations above show how the Centura washerless cartridge controls water flow:

1. **Off Position** — Fully inserted cam seals rubber sleeve against both hot and cold water supply ports.
2. **Mix Position** — Withdrawing cam permits sleeve to flex away from ports. Allows water to flow.
3. **On. . .Single Temperature** — Turning cam aligns bevel with one port, flat side with other. Result is one supply flowing and the other sealed.

Centura sink faucet features Celcon bearings on the spout post for smooth operation, easy spout swing action, and extended no-leak, no-drip dependability. Low-friction bearings help support the spout and virtually eliminate wear and tear for years of trouble-free service.

Centura faucets feature full 180-degree handle rotation for maximum control of water temperature. No more sudden temperature changes caused by minute handle movements. Handle also features more than one inch of "lift" for maximum volume adjustment.

Internal parts — other than the washerless cartridge — are precision machined from non-corrosive solid brass stock.

Contact your local Kohler representative for more information today . . .

P-H-C Industrial Supply Co., Inc.
1000 Siler Park Road P.O. Drawer F
Santa Fe, NM 87501
(505) 471-4811

Active Plumbing Supply
1500 Candelaria N.E.
Albuquerque, NM 87107
(505) 345-8587

KOHLER

KOHLER CO. KOHLER, WISCONSIN 53044

FORM P-880-75-778I