BRYAN RUBBER PLANT - INTERNATIONAL SHOE COMPANY, INC.

Willis M. Ponder, P. E.
President
ACR Energy Engineering, Inc.
Austin, Texas

ABSTRACT

This paper is an energy case study of a failing American manufacturing process suffering from:

. outdated ideas
. misinformation
. plant vs management misunderstanding
. counterproductive methods
. inefficient practices
. old equipment
. foreign competition
. rising utility rates

Surprisingly, foreign competition and rising utility rates were the motivation for the energy study and subsequent implementation but they had little to do with the real problems of excessive manufacturing costs.

This Project started in July 1981, and was finally completed in June 1983. It was very successful in immediately reducing utility costs by approximately 40%. It would be really wonderful to announce that the Plant, by lowering its utility costs that much, reestablished its share of the market, became profitable, increased output and employment, and is a now vital American industry. But, it's not. As of July 1985, it's barely hanging on.

THE PLANT

The Bryan Rubber Plant of the International Shoe Company was built in the optimistic 50's, with the provisions to double its size easily. An identical plant was envisioned alongside the main production building between the original production building and the administration building. The physical plant consists of:

MANUFACTURING BUILDING

. single story
. concrete floor on one level
. walls are concrete block with corrugated asbestos on steel
. roof is poured gypsum on steel
. clear height varies from 15 to 19 to 25 feet
. main buildings were built in 1953-54 with two additions in 1966
. inside area - 126,856 square feet
. significant window and translucent wall panel area

OFFICE BUILDING/LABORATORY

. single story
. concrete floor on one level
. brick and tile walls
. built-up roof - steel deck on steel
. fiberglass ceiling
. inside area - 7,784 square feet

The plant purchases electricity from the City of Bryan at primary voltage (2400 volts) and steps the voltage down through one 1000 KVA and one 2500 KVA transformers for distribution throughout the plant and office building. The primary electrical loads are large motor loads associated with various process-related equipment such as mixers, milling equipment, conveyor drives, water pumps, hydraulic pumps and compressors. During the base year (June 1980 to May 1981), the plant used 4,814,000 KWH ($180,549) with average monthly consumption fluctuating closely around 400,000 KWH. Electrical demand during this time varied from 1600 to 2000 KW. Electricity costs in May 1981 were $0.0462/KWH and $2.08/KW.

Natural gas is the other major energy source at the plant and is used to fire either of two 20,000 lb/hr steam boilers. Gas is also used for an oven and a domestic water heater in the office building. However, boiler consumption is by far the greatest user of natural gas, consuming an estimated 90% of the 85,743 MCF ($254,102) used from June 1980, to May 1981. Steam from the boiler was used by the chiller, presses, unit heaters, office HVAC system and in the laboratory. Gas cost for May 1981, was $3.32/MCF.

Between June 1980, and May 1981, the plant used 30,056,600 gallons of water at a cost of $17,179 or $0.57/1000 gallons. Water consumption is a problem with the existing chiller which required large volumes of water in its chilling process.

PLANT OPERATION

The Bryan Rubber Plant produces three basic products: cured rubber sheets, soles, and heels. Materials flow in one general direction through the plant from receiving to shipping. Materials handling includes the following processes: mixing, forming, curing, finishing, packaging, storing and shipping.

Depending on the product run, appropriate feedstocks are gathered and loaded into a Banbury mixer. Here the large chunks of rubber and other ingredients are broken down and thoroughly mixed. The mechanical energy applied to the mixture is almost completely converted to thermal energy; therefore, there is a significant rise in mixture temperature. Upon completion of the first mixing process, the hot rubber is dumped out through the bottom of the Banbury into the Dump Mill. The Mill, which has large counter rotating steel rollers, provides additional mixing and forms the batch of rubber into sheets approximately 1/2" thick. These sheets may then be cooled or fed directly into subsequent mills, depending on the ultimate product.

The forming process begins with additional milling to further mix and raise the temperature of the mixture. This milling operation takes place in either one or a combination of the Sheeter Mill, three Farrel Mills (84") or the 72" Mill. The various products have general paths through the forming section of the plant; however, they may vary significantly depending on the production schedule.

The rubber sheets are made by milling on the Sheeter Mill where a three foot wide continuous strip is made. The strip is cooled on a conveyor system, then cut and stacked on the 3 x 3 stacker. Sole blanks are made by milling on the 72" Mill where narrow continuous strips are made. These strips are cut to size on the Rotor Shear, then cooled on conveyors. Heel blanks are made by either punching the blanks out of sheets using the Model C Bean Punch or by using a Barwell Heel Extruder. The final forming of the soles and heels is accomplished during the curing operation.

The curing of the rubber sheets is done in the five hydraulic slab presses. The sheets are stacked between steam-heated platens and maintained at approximately 370°F, while as much as 1800 psi pressure is applied. There are ten sole presses and five heel presses where the blanks are formed into their final shape and cured at about 370°F.

The only finishing the heels and soles require is the removal of trimming of excess rubber. The sheets are sanded and buffed to the desired surface texture and thickness. They may also be painted or coated on a print line to any desired appearance, such as a leather look. The finished products are then inspected, packaged, and stored in the west warehouse area.

STEAM GENERATION

Plant steam is generated by either of two, 20,000 #/hr water tube, natural-gas-fired boilers supplying 175# saturated steam for process and heating use. Each boiler has provisions for burning diesel fuel but are not used in that mode of operation. It is normal operating procedure to fire only one boiler at a time.

In the base year, International Shoe Company consumed 85,743 MCF of natural gas, of which 77,743 MCF was consumed by the boiler to generate steam. The remaining 8,000 MCF was consumed directly in a gas-fired process oven and for domestic hot water in the administration building.

STEAM DISTRIBUTION SYSTEM

(Refer to Steam System Drawing.) From the boiler, 175# steam is distributed overhead via an 8" steam line to point A where a 4" line runs down to the service tunnel. 175# steam is distributed to twenty steam presses. No condensate was returned to boiler, although condensate returns were in place. 195°F condensate was dumped into a drain near the boiler.

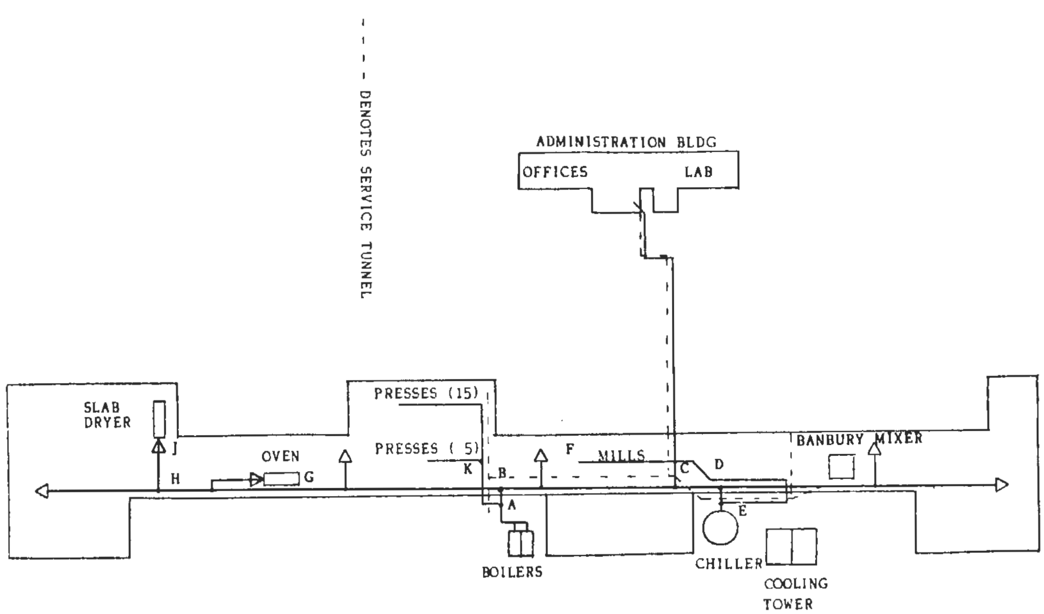
At point B, 8" steam line splits where a 6" line runs east and a 4" line runs west to both ends of the production building at 175#.

At point C, a 4" steam line runs overhead to the north side of the production building and then down to a tunnel to the administration building. Condensate is returned.

At point D, a 6" line supplied the steam-jet refrigeration unit. No condensate was returned.

At point E, a 1 1/2" steam line drops to the tunnel and runs back west to two small steam loads in the mill area at point F. No condensate was returned.

An oven at point G is served by the west end steam line. A PRV reduces steam pressure to 15# to serve two 200,000 BTUH steam units. Condensate was returned.



STEAM SYSTEM DRAWING

Steam for the slab dryer was tapped at point H and a PRV reduces 175# steam to 15# for utilization. Condensate was returned.

At various points in the building, PRV's are installed to serve 15# heating units. The entire 15# steam system was charged continuously.

The general condition of all steam pipe insulation was rated as poor and wet. Charged, but unused, 175# steam lines were numerous and no provisions existed for turning off the mostly unused steam system.

STEAM CONSUMING SYSTEM

Presses: The plant has 20 hydraulic operated, steam presses operated 80 hours per week. Because of reported moisture condensation in the machines, the presses were heated an additional 41 hours per week. Each press consumes 95#/hr when loaded and about 1/5 (estimate) that amount when idle.

Slab Dryer: Consumes 100#/hr (estimate) at 15# when operating. Operates one shift per day.

Oven: Contains two 200,000 BTUH steam coil heaters @ 15#. Operated loaded 80 hours per week, unloaded 41 hours per week.

Heating System: Utilizes thirty 200,000 BTUH steam coil heaters @ 15#. PRV's are located in various places along the main 175# steam lines in the production building. Steam was supplied to the office HVAC 121 hrs/wk. Production heating system was left on continuously 121 hours per week during the 14 week heating season.

Mills: Very little steam is used by the mills. Most of the mills' heat is friction generated and is removed by chilled water. Two machines utilize approximately 10#/hr, 40 hours/week.

Steam-Jet Water Vapor Refrigerating Unit: The barometric condensing unit was the major steam consuming system in the plant. It used steam to create a vacuum which, in turn, generated chilled water in the evaporation section. The capacity of the unit was 340 tons. However, only two of four boosters were operated consuming approximately 5,500#/hr of 175# steam. Naturally, no condensate was returned. The chiller was operated 24 hours a day, seven days a week for 36 weeks per year. When the temperature dropped low enough to turn the heating system on, the cooling tower supplied cooling water directly by connecting the chilled water and condensing water systems together.

CHILLED WATER UTILIZING DEVICES

Mill Machines: Use chilled water to dissipate friction generated heat produced by material and rollers. Approximately 100 tons of refrigerating capacity is required but is only needed 40 hours per week with a 50% load factor.

Office Cooling: Two AHU's utilize chilled water for cooling offices and laboratory. These units were operated continuously, even on weekends. Original cooling capacity was 35 tons but, because of insulation deterioration in the tunnel, the actual capacity was quite reduced.

Air Compressor: Compressed air to the plant was provided by a dual Chicago Pneumatic reciprocating air compressor driven by a 200-HP synchronous motor. Cooling water from the chiller was supplied by two uninsulated chilled water lines in the tunnel at 120 gpm with a 14^{O}F temperature rise. This was about a 65-ton load but, because of the non-insulated chilled water lines, an 8^{O}F rise was observed between the air compressor and the main CHW line.

Note: If the barometric condenser was operating at half capacity, as discussed before, 170 tons of cooling water should have been generated. However, we accounted for over 240 tons use. Since a barometric condenser has no capacity controls, other than turning on and off more boosters, something must suffer. In this case, cooling water temperature suffered. Capacity was substantially increased at the expense of temperature. Instead of 55^{O}F CHWS, 62^{O}F CHWS was generated. No one could tell us why even 62^{O}F water was required. We assumed it was needed.

COOLING SYSTEM AUXILIARIES

Chilled Water Pumps: Chilled water was distributed by two 20-HP chilled water pumps with a manufacturer published pump efficiency of 35%. Some pumps were operated 168 hours per week, 50 weeks per year.

Cooling Tower Circulation Pump: Water used for condensing was cooled by a two-cell cooling tower, circulated by a 30-HP centrifugal pump. The pump was operated 168 hours per week, 50 weeks per year.

Cooling Tower Fan Motors: One cell was equipped with a 20/5 HP, two-speed fan motor. The other cell was equipped with a 20-HP single-speed fan motor. Both were operated 168 hours per week, 50 weeks per year on high speed.

Condensing Water Pump: Condensing water to the barometric condenser was supplied by a 30-HP centrifugal pump, operated 121 hours per week, 36 weeks per year.

Cooling Tower: Two cell Baltimore Air Coil towers; 560 tons each cell at 78^{O}F WB.

LIGHTING SYSTEM

Lighting through the plant was provided by two-bulb, 40-watt fluorescent fixtures and lamps. While light levels were adequate for production, it was apparent that illumination had fallen below design levels through much of the facility due to an accumulation of processing particulates on the bulbs/fixtures and also from general corrosion and loss of electrical integrity of the fixtures themselves. During the audit, many fixtures were observed with burned out or flickering bulbs.

THE AUDIT

A plant employee saw an ad in *Energy User News* about a shared savings approach to energy conservation/reduction and relayed this information to corporate headquarters in St. Louis. The shared savings firm, CSL Company, was contacted and the process was started. ACR Energy Engineering, Inc., of Austin, Texas was hired by CSL to perform an energy audit to identify projects which had a simple payback of less than 1.5 years.

When we visited the plant in June 1981, we thought we had died and somehow ended up in hell. The plant impressed us as something from a Dickens novel; steam escaping from leaks everywhere, tunnels filled with vapor clouds formed by uninsulated chilled water lines in contact with live steam, a screaming steam jet refrigeration unit (which we had never even heard of before) and a plant covered with carbon black particles. We were not immediately sure of what could be done but we knew beyond a doubt that opportunities were great.

The night of the first day was spent in a motel room reading all we could find on the Ingersoll Rand refrigeration machine. We, at first, thought it was some sort of strangely configured absorption machine but soon discovered it produced chilled water by creating a vacuum which caused water to boil at a low temperature (55°F in this case).

We could not find out why 55°F water was necessary, except for space cooling, and why it was thought to be the "ideal" cooling water temperature for the process. Even though we couldn't determine "why" we didn't challenge the use of it and proceeded with the notion that there had to be a better method of providing it. A year after the installation was complete, we found that 55°F water was not only unnecessary, it was really undesirable. Cooling water temperatures of 80-100°F are more appropriate delivered in larger quantities.

The second major misuse of steam was in the steam presses, which were used to cure slabs, soles, and heels. Through the years, someone had taken all the traps off the presses and replaced them with a piece of pipe. A piece of pipe open to the atmosphere. No condensate was returned as 150-175 psi steam was running wild through the presses. At times of heaviest use the boiler couldn't keep up with the steam demand and the second boiler was brought on line to provide the additional capacity.

We were informed by the plant operating people that close temperature control was "critical" and that the press temperature absolutely could not vary more than 1/2 to 1 degree F or the product would be ruined. It seemed a little strange and unbelievable that such a close tolerance could be set and maintained with instruments and a control system that hadn't been calibrated in ten years; but, we didn't challenge that either.

The third major misuse of steam (chilled water) was for providing compressor head and jacket cooling for the compressed air system. The 55°F chilled water was run uninsulated through the tunnel system where 8°F was added just from the ambient environment. A crude heat exchanger was fashioned from a vat and some copper tubes to temper the chilled water temperature down to Chicago Pneumatic's recommended temperature of ambient temperature.

Steam leaks and heat loss from charged but unused steam lines made up the remainder of the steam misuse.

Major electrical misuse was concentrated in the cooling water system where 140-HP of pumps and fans were required just to operate the steam jet refrigeration unit. Preliminary calculations showed that by redesigning the entire system around an electrical chiller, the total power required would not be appreciably more than that already consumed just by the auxiliaries and it could be turned off when not needed.

One large extruder used a DC voltage variable drive and all large motors were synchronous, which required a DC voltage also. The DC was provided by motor-generator sets which were unloaded most of the day.

The biggest problem, however, was not equipment related. It was misinformation and, in some cases, no information. The plant personnel knew how to make rubber products but had never questioned the process. The requirements had simply evolved or been handed down for 25 years from one to another. Opposing management was simply a way of life.

THE PROBLEMS

The problems uncovered by the audit were as follows:

- inefficient primary cooling plant
- one cooling plant serving three different loads - mills, air compressors, people
- inoperative condensate return system
- excessive operating hours
- steam leaks and missing insulation
- excessive water consumption, leaks
- excessive electrical auxiliaries for cooling
- no air conditioning in labs and offices
- maintaining 55F cooling water
- untrapped steam lines

THE SOLUTIONS

Usually, corporate management is either unwilling or unable to invest the necessary funds into energy and cost reduction techniques. This was not the case at the Bryan Rubber Plant. They were to get the benefits of the cost reduction projects, share in the savings (50%) for seven years, and eventually own the equipment. However, to finance the project, CSL was offering a limited partnership deal to investors as a tax write-off benefit to the investors. The "deal" did not attract sufficient investors and was never funded. Our report and recommendations lay dormant for several months.

Corporate management couldn't ignore the fact that someone was willing to invest in a shared savings project and finally decided to implement a modified project themselves. We were asked to re-evaluate our original recommendations and use current energy prices and resubmit our findings. The final recommendations were:

- Remove steam-jet refrigeration unit from service.
- Install 100 ton (nominal) water-cooled, two-stage water chiller to provide source of cooling to production building process machinery.
- Install new chilled water loop pump and controls to supply water to chiller chilled water loop.

.Install new chilled water circulation pump and controls to supply water to production building process machinery.

.Replace all PVC chilled water lines in production building with schedule 40 black steel.

.Remove all damaged insulation on chilled water lines.

.Repair and reinsulate all chilled water lines.

.Install 30 ton (nominal) air-cooled, two-stage water chiller to provide source of cooling for administration building and laboratory machines.

.Install new chilled water pump and controls to supply chilled water to administration building HVAC unit and laboratory machines.

.Install automatic water make-up system to production building and administration building chillers.

.modify existing Baltimore Air cooling tower and install accessories to provide sufficient water flow to tower wetted area.

.Install automatic water treatment system for condensing water system.

.Install new condenser water pump and controls to provide condensing water supply to production building chiller, cooling tower, and two air compressing units.

.Connect air compressors to condenser water loop pump to provide cooling to air compressor heat exchangers.

.Install automatic control system with telephone modem with remote programming capabilities to control automatic operation of production building and administration building chillers.

.Repair condensate return system from rubber presses.

.Install individual steam traps on each steam press platen.

We estimated that approximately $200,000 per year could be saved at a total installed cost of $225,000.

THE BIG PROBLEM

After weeks of consideration, corporate management decided to implement the measures. The big problem was that the plant personnel didn't want it. In fact, they didn't want it at all. Their objections were:

. A 100 ton unit could not supply sufficient quantities of 55F chilled water for machine cooling.

. They didn't believe in steam traps.

. They believed that the administration building would become saturated with moisture if the air conditioning was turned off on weekends.

. It simply was not worthwhile to accomplish anything corporate management wanted. It wasn't even possible.

Even with plant operations' disapproval, the project was funded, started, and finished, and is in operation today.

THE RESULTS

. One month after implementation, gas usage dropped to one-fourth the previous month's consumption at the same production levels.

. Electricity usage declined by $5,000 per month.

. Water usage was reduced to one-third the previous month's usage.

. The administration building was cool for the first time in ten years.

. Steam press operators were able to see the finished product without the steam clouds.

. The plant was noticeably quieter and cooler.

SUMMARY

Based upon previous experience with a rubber manufacturing plant, we absolutely had no business trying to tell a rubber plant manager how to make rubber. And, we didn't try.

We observed a relatively simple thermodynamic process and recommended and installed some modern techniques to help them do what they knew best how to do. We also observed the more complex problems of the dynamics of personalities and motivational forces of employees and used them to our advantage.

For example, we didn't argue with the assumption that 55 degree cooling water was necessary. When the chiller, indeed, could not and did not keep 55 degree water supplied to the machines we adjusted the only temperature monitor they had to reflect a lower temperature and they've been happy ever since.