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SYSTEM FOR REDUCING HEAT LOSSES FROM INDOOR SWIMMING POOLS BY USE OF AUTOMATIC COVERS

REPORT NO. 5

by

LÖF ENERGY SYSTEMS, INC., GRANTEE

for period from January 1, 1995 to March 31, 1995

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I. TECHNICAL SUMMARY

A. Product Improvements

1. Improved flotation edges of woven polyethylene covers by use of laminated foam strips sewn to cover.
2. To obtain improved control of tow-rope tension, designed alternate rope spool brake employing heavy duty brake lining material held in V-belt sheave groove by metal strip and extension spring.
3. Designed alternate rope spool brake employing above material and electric solenoid to loosen brake during cover deployment cycle.
4. Redesigned closures on pockets in pool covers for better retention of battens and stiffeners.
5. Modified stop-balls to permit their placement on tow ropes without requiring lengthy movement from rope end.
6. Designed, built, and tested a time meter for showing duration of pool cover use on pool.
7. Designed simplified controller which employs mechanical stopping of cover motion, and motor shut-off by switch release.

B. Test and Demonstration Installations

1. Improved roll up alignment of cover in test system at Denver Boys and Girls Club by placement of small patch near edges of cover to enlarge diameter of roll edge at suitable positions.
2. Constructed second motor unit for demonstration systems at Skyland Pool.
3. Designed and procured (from subcontractor) two large covers for motorized reels and two short covers for manual reels at Skyland Pool. Inspected covers, returned for corrections, reinspected and accepted covers.
4. Installed, tested, and adjusted 4 cover systems and controls at Skyland Pool - one motorized with photo-electric cell control, one full length (24 feet) motorized unit with stop-ball control, and 2 manual reels and covers.
5. Arranged installation (by Public Service Company of Colorado) of two gas meters for measurement of fuel supply to pool water heater and to ventilation air heater.
6. Modified ventilation at Skyland Pool to conform with conventional practice, and procured and installed automatic humidity control system.
7. Initiated testing and monitoring of fuel use (by C. Smith, consultant) at Skyland Pool, when covers are in use and when they are not in use, for savings evaluation.

C. Dissemination of Information

1. Prepared draft of instruction manual for manufacture of system.

2. Planned and scheduled a meeting at Skyland Pool (April 21, 1995) for announcing completion of demonstration system, disclosing results of energy use measurements, and presenting system to City of Denver. A copy of materials distributed to meeting attendees is appended.

II. DESCRIPTION OF PROJECT ACTIVITIES AND RESULTS

A. Product Improvements

1. Improved cover edge design.

The previously used enclosed rope reinforcements of the cover edges have not been satisfactory because of their alignment irregularity and their lack of bouyancy. Pool water could trickle over low points onto the top of the cover. When the cover was being wound onto the reel, diameters of the two ends of the cover roll varied considerably depending on how closely the narrow rope edges stacked on top of each other or whether they formed a side-by-side pattern. Inconsistent and irregular rolls of cover resulted, often requiring unrolling the cover and another retrieval.

A new edge design greatly reduces the problems previously encountered. Strips of 1/8 inch closed cell flexible foam laminated between two layers of woven polyethylene cover material are sewn to the top surface of the cover along both edges, in widths of 6 to 8 inches. Good flotation has been obtained and the alignment of the cover roll on the reel has been materially improved. Random wandering of the cover during retrieval has been greatly reduced, and slight misalignments can be corrected by slightly increasing the thickness of material in a stiffener pocket at one edge of the cover or at the other edge.

2. Improved rope spool brake

The rope spool brake developed under this grant requires several special hand-made aluminum parts and involves considerable assembly labor. Careful field adjustment is also required. In an effort to reduce the substantial cost of this component, the previously used design employing a spring tension brake band has been improved by replacing the belt-type material with a strip of durable brake lining held in the groove of the V-belt sheave by a narrow aluminum or brass strip, to one end of which the extension spring is attached. The other end of the metal strip is fastened by a threaded bolt of adjustable length to the base of the motor box in line with the groove of the V-belt sheave. The operating principle is the same as that of the obsolete brake previously used, but the durability of the replacement brake band is so much greater that the principal drawback of the earlier design is avoided.

The new brake has been shop-tested, and it has been installed in one of the Skyland Pool demonstration units (No. 2 unit) for long-term evaluation. Final decision on its adoption will be deferred until sufficient experience has been obtained.

3. Solenoid brake design

A further development of rope spool braking equipment involves use of the concept described above in section II A 2, in combination with an electric solenoid. The objective in this design is to provide to the rope spool positive braking action (resistance to rotation) when the cover is being retrieved (rope being pulled off the spool) and when the cover is resting on the pool or on the storage reel, but no braking when the rope is being wound onto the spool during cover deployment. The spring-tensioned brake described in section II A 2, and the new brake developed during the first months of this project both reduce the braking action during cover deployment, but they do not permit entirely free rotation of the rope spool during that operation.

Use has been made of a power-driven solenoid to completely relax the spring tension on the brake band described in section II A 2, when the tow rope is being wound onto the spool. The solenoid is a "push-pull" type, the plunger of which is held by an extension spring to provide tension on the brake band fastened to the opposite end of the plunger. When the control switch actuates the down relay, power is supplied to the solenoid, the plunger of which is driven upward to relieve the tension on the brake band as the cover is pulled onto the pool by the rope being taken onto the spool. When the cover is fully deployed or retrieved, power is shut off, the solenoid is deactivated, the spring restores tension to the brake band, and the brake prevents unrolling of the spool and sagging of the tow rope.

4. Redesign of pockets for battens and stiffeners.

Instead of open ended sleeves for battens spanning the cover width, an end flap has been designed which permits easy insertion of the tubular PVC battens but which also folds over the batten end to prevent its sliding out of the retaining sleeve. Shorter pockets for enclosing stiffener strips at the two edges of the cover have also been provided with similar end flaps aiding insertion and retention of the strips.

5. Stop-ball modification

The correct positioning of two large beads, or "stop-balls" on the tow rope has required access to at least one end of a rope usually about 200 feet long. Besides the need for sliding the balls along the rope to the right positions, knots preventing further movement of the balls have been necessary, also requiring access to the rope ends.

To reduce installation labor, stop-balls have now been split in half along the central hole, drilled transversely for use of bolt and nut to reassemble the ball around the rope at any desired position. Knots are made unnecessary by making a loop of rope around the central bolt as the ball is reassembled. The labor of installing and adjusting the tow rope has been substantially reduced by this improvement.

6. Time meter

Verification of pool cover use is sometimes difficult when pool operators and pool managers do not agree on the importance of saving energy and costs by covering the pool when not occupied. To provide proof and duration of pool cover use, a time indicator has been designed for monitoring and accumulating the elapsed time between placement of cover on the pool and its removal from the pool. Two low-cost 24-volt single-pole, double-throw relays and a digital elapsed-time indicator are coupled to appropriate terminals in the switch box for convenient monitoring. A prototype timer has been provided for use in the Skyland Pool installation.

7. Simplified controller

The replacement of maintained control switches with momentary switches, (for reliability and safety) makes the automatic cover-stopping features less important. The operator must continue to depress the switch to run the motor, and on release of the switch, the motor stops. This design is compatible with the use of stop-balls on the tow rope to stop rope movement before a motor shut-off is needed. When the cover is being placed on the pool and the tow-bar reaches the far end of the pool, further movement of the tow-rope is prevented by a stop-ball entering the turn-around pulley, thereby terminating movement of the tow bar. Slippage of the Morse clutch on the rope spool drive permits continued operation of the motor and reel after rope motion is stopped. The operator continues motor operation to unwind sufficient cover material to cover exposed water near the end of the pool beneath the reel. When covering is complete, the operator releases the switch.

When the cover is fully removed from the pool and wound onto the reel, further rope movement is prevented by another stop-ball entering the other turn-around pulley on the pool wall opposite the reel wall. The position of the stop-ball on the tow rope is such that the tow bar must stop moving when it is slightly below and in front of the reel. Even if the operator delays release of the switch, the Dalton clutch on the reel drive-shaft will permit the motor to run without turning the reel.

The elimination of automatic stopping either by photoelectric control or by stop-bars and snap-switches can reduce maintenance and repair calls as well as reduce equipment prices by \$200 - \$400. No system lacking one of these auto stop systems has been installed, but the test system at the Denver Boys and Girls Club has recently been modified by removing the stop-bar, snap-switch automatic stop feature. Limited testing has indicated satisfactory and reliable operation. Continued evaluation will be conducted before decisions as to adoption are made.

B. Test and Demonstration Installations

1. Improve cover centering on reel.

The wandering and spiralling of covers being wound on reels has been a chronic problem. Efforts to minimize irregularities have included the use of a guide spindle (second tube above reel tube, over which cover passes), spiral rubber windings on guide spindle, enlargements of central section of reel to increase tractive force at center of cover, and recently, replacement of rope-filled cover edges by substituting sewn-on laminated foam strips (topic A 1 in Product Improvement section). The last design change has proved the best to date. Good roll-up patterns are now usually obtained, but occasional misalignments indicate the need for further improvements and corrective measures.

A beneficial design modification has been developed in the wide cover at the Boys and Girls Club. Pockets extending 12 to 30 inches from the cover edges toward the center of the cover enclosing 1/8-inch by 1 1/4-inch stiffener strips of high density polyethylene, are located in several positions along both edges of the cover. Normally one stiffener strip is placed in each pocket. If the cover is seen to wind unevenly on the reel, spiralling to the left for example, the amount of cover material being pulled onto the left end of the roll is slightly greater than that on the right. This action indicates the left edge of the roll is larger than the right and that, in effect, the left is thicker than the right. The right edge can then be thickened and enlarged by inserting additional stiffener strips in the pockets on that edge at suitable locations. Better centering of the cover on the reel is then obtained. It is even possible to correct misalignment of a "bent" cover having imperfect assembly of panels, by use of thicker pocket filling in one edge along part of the cover length and in the other edge along another part of the cover.

2. Motor unit for Skyland pool

One of the motor units for the demonstration systems at the Skyland pool was constructed and bench-tested during the previous quarter. The second unit was built and bench-tested during the present quarter. The two units are identical except for the controllers and rope-tensioning systems (rope-spool brakes). Both are 24-volt systems, one with automatic stop provided by photoelectric cell and the other by snap switches actuated by stop-balls pressing against movable gate bars at the front of the motor box. The two control systems are diagrammed in Report No. 4.

3. Cover design, procurement, and inspection

Four pool covers employing design details based on successful tests at the Boys and Girls Club were ordered from the company's regular supplier, American Canvas Co. Blue woven polyethylene, reinforced by laminated foam strips at edges and in a central band, was specified. Two large covers, 22 1/2 x 108 ft., 17 1/2 x 106 ft., and two smaller covers each 17 1/4 x 53 ft. were ordered.

On delivery, the covers were carefully inspected and found to require return to the fabricator for correction of closure flaps on the pockets for stiffener strips and on the end flaps of sleeves for long battens. Except for those alterations, the covers were accepted as fully satisfactory.

4. Installing and testing demonstration covers

Two motor units, reels, control station, tow rope mounting pulleys, and pool covers were installed at Skyland pool under the requirements of Task 4. Electric service to the two motor boxes was provided by a licensed electrical sub-contractor, and the 24-volt wiring to wall switch station was installed by the project personnel.

Installation problems were minimal, approximately 80 man-hours being required for completion. Adjustment and testing then prepared the equipment for monitoring of performance by means of comparison measurements of fuel usage with and without pool covers in place.

The diving area at one end of the pool was also provided with two covers on manually cranked reels. These units were installed so that the entire pool could be covered for comparative testing, as well as saving energy when regularly used.

5. Installation of special gas meters

In order that accurate measurement of heat requirements and energy savings at the Skyland pool demonstration could be determined, it was necessary to install special meters for "sub-metering", that is, metering of gas consumed in the pool water heater ("boiler") and in the heater designed to supply heated fresh air and recirculated air to the natatorium. Without such individual fuel measurements, monitoring of savings achieved by use of pool covers could not have been accomplished.

With the valued cooperation of the Public Service Co. of Colorado, digital gas meters were installed on the pool water heater and on the natatorium air heater for use during the period in which the system is being evaluated. Additional facts concerning the measurement of air-heating energy requirements are included in the following section II B 6.

6. Ventilation modification and humidity control

The Skyland natatorium had been ventilated by use of an unconventional air flow pattern. Although there is a conventional heating-ventilating unit on the natatorium roof, its ventilation function (fresh air supply) was not being used. Instead, air entering other parts of the large building (gymnasium and exercise rooms) flowed through open areas and passages into the natatorium, then to exhaust fans for outdoor discharge over the natatorium roof. The heating-ventilating unit on the natatorium roof was used only to heat air being recirculated from the natatorium. Fresh air dampers had been blocked in closed position. No humidity control was provided, and operating conditions were such that natatorium humidity was usually much lower than the recommended 50% to 60% level. Unusually high rates of evaporation and of heat supply to the pool water were therefore observed.

The ventilation system was modified to conform with modern recommended practice. Besides permitting measurement of air heating requirements and savings previously prevented by multiple use of the same air supply, the changed air flow pattern made possible the control of humidity in the natatorium. Modifications comprised (1) blocking flow of air into natatorium through hallways and doorways from other parts of the building, (2) reactivating closed fresh-air dampers in the natatorium fresh-air supply unit, (3) procuring and installing (with assistance from the City of Denver equipment maintenance staff) a humidistat for controlling the fresh-air supply dampers to maintain a preset humidity level in the natatorium, (4) providing control of exhaust fans to match fresh-air supply rates, and (5) arranging installation of gas meters by Public Service Co. of Colorado to measure fuel use exclusively for heating ventilation air supplied to the natatorium.

7. Measurement of gas use at the Skyland pool

Monitoring began on March 2 shortly after installation of the pool covers. Mr. Charles Smith set up instrumentation for sensing and recording water temperature, air temperature and dew point in the natatorium, and outdoor dry bulb and wet bulb temperatures. Conditions were recorded at 6-minute intervals. Runs were commenced when use of the pool ended about 7 PM; runs were completed about 7 AM before swimming started. The meter through which gas is supplied to the pool boiler was read at the start and end of the run. Preliminary tests on the air-heating system were also made, but the initial lack of a gas meter on that supply and the absence of humidity control severely limited the usefulness of the air-heating data.

On March 27, the humidity control system was successfully completed as described in section II B 6 (after the humidity controller first installed was found unsatisfactory and was removed). On March 28, a digital gas meter was installed as described in II B 5. The first complete performance test, with accurate humidity control and measurement of gas use for water heating and air heating in an uncovered pool was conducted during the night of March 28-29, with excellent results. The first complete test on the fully covered pool was conducted during the week-end of April 1-3, also with definitive results. Large energy savings resulting from use of the covers were observed.

In addition to gas meter readings, electric energy use for the exhaust fans was obtained by reading a timer coupled to the burner control. Burner operation is simultaneous with open fresh-air dampers and exhaust fan operation, so duration of burner operation provides data for determining exhaust fan power use. Additional performance tests are scheduled in April, and the processing of data and the determination of energy and cost savings will provide the basis for the final report.

C. Dissemination of Information

1. Assembly Manual

Complete instructions for constructing the mechanical and electrical equipment developed in this project have been drafted and revised. A final form of the manual is nearing completion at the end of the period covered in this report.

2. Planning of Presentation of Pool Cover System

Although the pool cover presentation meeting will take place in the next quarterly period, extensive planning and preparation have taken place during the period covered in this report. A tentative program and a list of invitees are included herein. The principal participants in the project, including DOE, the Denver Parks and Recreation Dept., Public Service Co. of Colorado, Mr. Charles Smith, and this grantee, will explain their roles and summarize the results of their work. Operation of the pool cover will be demonstrated, and the system will be officially presented to the City of Denver. Reports of the event will be made available to all interested parties.

III. MANAGEMENT SUMMARY

For reasons presented in a December 5, 1994 letter from this grantee to the DOE Denver Support Office, and summarized in Progress Report No. 4 of January 15, 1995, a six-month extension of the grant to a final date of September 30, 1995 was requested. That request was approved as of March 20, 1995, and received and accepted by grantee immediately thereafter. The management and staff of Lof Energy Systems wish to express their appreciation to DOE for this action.

The revised performance schedule (Revision 5) in Progress Report No. 4 is presented in this report without change.

Task 1, pertaining to cover materials, cover fabrication, and testing has been completed. Woven polyolefin (polyethylene or polypropylene) has been selected as the best material for indoor pool covers, and foam-laminated material has been chosen for sewn-on edge strips for reinforcement, flotation, and improved alignment on reels.

Except for preparation of manuals, Task 2 is complete. The lengthened reel, widened cover, and improved motor box and controller have been fabricated and tested. Two types of automatic motor stop equipment have been adopted, and two new braking (rope-tensioning) systems have been successfully tested. Final selections will be made during the remaining period of the grant. In addition to the nearly finalized assembly manual, installation, operation, and service manuals will be prepared during the next quarter.

Recent progress in Task 4 now places Task 3, UL approval of system, in a priority position. A first step has been taken, by securing official approval, by a licensed electrical engineer, of both electrical systems used in the Skyland pool demonstration installation (Task 4). The schedule indicated in the Jan. 1, 1995, Revision 5, will be followed.

In Task 4, only the monitoring and reporting of savings and the dissemination of results remain to be completed. Monitoring will be completed in April and a report of performance of the pool cover system should be available shortly thereafter.

Dissemination of results will first take place at the Presentation meeting April 21. As indicated in the Performance Schedule, Revision 5, subsequent disclosure and publication plans are expected to be finalized during the April-June quarterly period. It is possible, however, that publication of the pool cover performance results will be contemporary with the preparation of the Final Report, Task 5, scheduled for completion by the September 30, 1995, termination of the project.

LÖF ENERGY SYSTEMS, INC.

REVISED PERFORMANCE SCHEDULE

REVISION 5
JAN 1, 1995

IV. FINANCIAL SUMMARY

Total project expenditures to March 31, 1995, have been \$92,119, of which \$77,219 is the federal share and \$14,900 is the grantee share (14%). Combined DOE and grantee expenses in the upcoming April-June quarter are estimated to total \$28,276, bringing the estimated costs of the project through June, 1995, to a total of \$120,395. This total exceeds the \$99,453 approved budget for the grant, of which the federal share is \$83,310 and the grantee share is \$16,143. The entire approved federal share of \$83,310 has been received by the grantee.

As stated in previous reports (No. 3 and No. 4), unanticipated project costs have required expenditures exceeding budget estimates. The funds requested for costs incurred in Jan. through March, 1995 and for estimated outlays in April through June will consume more than the balance of the present grant. We have therefore submitted a formal request, by letter of Feb. 20, 1995, to Elliott Levine in the DOE-ERIP Office, for \$16,690 additional DOE support of the work in the remaining six months of the project, primarily for pursuit of UL certification of the system and for the preparation of reports, manuals, construction bulletins, and technical papers. If this request is granted, the total authorized federal share of the revised project cost will be \$100,000.

The estimated total cost of the project through June, 1995, is, as shown above, \$120,395, of which the 84% federal share would be \$100,971. This federal share slightly exceeds the sum of the original grant allocation and the requested supplement, so if the requested supplement of \$16,690 is approved, grantee requests payment of \$16,690 to bring total federal payments to \$100,000. Grantee will then pay its normal 16% of the \$120,395 estimated total project costs, viz. \$19,424, plus \$971 not covered in the federal share. The final cost distribution would then be \$100,000 federal and \$20,395 grantee. If costs exceed the \$120,395 estimated total, grantee agrees to defray all project costs exceeding that estimate.

Request is made for payment of \$16,690, which is the requested supplement to the original grant, and which is also the difference between the revised \$100,000 federal share and the \$83,310 previously provided.

WELCOME!

- CITY OF DENVER •
- PUBLIC SERVICE CO. OF COLORADO •
- U.S. DEPARTMENT OF ENERGY •

POOL COVER
DEMONSTRATION
& PRESENTATION

SKYLAND RECREATION
CENTER, DENVER, CO.

- *by* LÖF ENERGY SYSTEMS •

April 21, 1995 ... 2 PM

Deployment of No. 1 cover onto Skyland pool during L.E.S.I./D.O.E.. presentation meeting on April 21, 1995.

Prototype cover constructed of several different cover fabrics and construction methods at Boys Club in Denver.

Both motorized covers in stored position at Skyland pool. Note total availability of deck space for activities.

Close-up of the No. 2 unit at Skyland pool. Guide rope is taut, providing excellent clearance for regular pool side programs.

LÖF ENERGY SYSTEMS, INC.

Energy Saving Indoor Swimming Pool Covering Systems
We Support the Department of Energy's RSPEC! program and Smart Pool concepts

Presentation of the Swimming Pool Cover System at the
Skyland Recreation Center to the City of Denver, Apr. 21, 1995

Information on Automatic Pool Covering System

To maintain comfortable and healthful temperatures in an indoor swimming pool, heat must be continually supplied to the pool water and to fresh air that must be brought in for ventilation. Nearly all the heat added to the water is lost by evaporation into the air above the water surface. That very moist air must then be removed and replaced with relatively dry outdoor air that requires heating during most of the year. The cost of natural gas for supplying heat in a typical institutional pool is \$10,000 to \$25,000 per year.

When the pool is not being used, typically half to two-thirds of the time, evaporation and the resulting heat demands can be eliminated by placing impervious covers on the water surface. On a schedule of use such as at Skyland, the pool can be covered and evaporation suppressed about two-thirds of the time, thereby saving about ten thousand dollars per year. Determination of the actual savings achieved by use of pool covers is the principal objective of this project. The program goal is the development of the technology and tools for achieving major reductions in the nation's waste of energy.

With the cooperation of the Parks and Recreation Department of the City of Denver, Lof Energy Systems, Inc., has designed, manufactured, and installed two of its motorized cover systems and two manually operated covers at the Skyland pool. The project is funded by an Inventor Grant from the U. S. Department of Energy. With the aid of gas metering facilities provided by the Public Service Co. of Colorado, Mr. Charles Smith, energy specialist from Colorado State University, is measuring fuel reduction and cost savings resulting from use of pool covers. For the first time anywhere, actual data on energy conservation in a covered swimming pool maintained at closely monitored conditions has been obtained. A computer program developed by the Denver Support Office of DOE for predicting energy savings by use of pool covers will be validated by comparison with data obtained in this project. Dissemination of the results through publication in technical journals, pool and spa magazines and informational bulletins, and other appropriate media is planned.

PLAN VIEW OF SKYLAND SWIMMING POOL

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ENERGY USE AND SAVINGS
 DURING OVER-NIGHT POOL CLOSURE (12 hours)
 Actual measurements in April, 1995

TOTALS FOR 12 HOUR OVER-NIGHT POOL CLOSURE

NOTE:
 • CCF = HUNDRED
 CUBIC FEET OF
 NATURAL GAS

UNCOVERED POOL
 59.7 CCF OF NATURAL GAS USED TO HEAT WATER
 59.9 CCF OF NATURAL GAS USED TO HEAT AIR

COVERED POOL
 14.5 CCF OF NATURAL GAS USED TO HEAT WATER
 15.9 CCF OF NATURAL GAS USED TO HEAT AIR

SAVINGS
 45.2 CCF OF NATURAL GAS USED TO HEAT WATER
 44.0 CCF OF NATURAL GAS USED TO HEAT AIR

ANNUAL COSTS & SAVINGS shown in dollars

NATURAL GAS FOR HEATING WATER
AND FRESH AIR DURING POOL
CLOSURE (5252 HRS/YR)

Above display obtained by using data from covered and uncovered runs for test periods in April and projecting those results to 12-month year by use of average Denver weather data.

FINANCIAL SUMMARY

ECONOMIC RETURN FROM POOL COVER USE

OVERVIEW

ANALYSIS FOR SKYLAND RECREATION CENTER POOL

1. INSTALLED COST OF TWO MOTORIZED LOF POOL COVERS &
TWO MANUAL COVERS ON 4724 SQ. FT. OF SWIMMING POOL
\$34,800
2. PROJECTED ANNUAL SAVINGS OBTAINED BY POOL COVER
USE - 5252 HRS/YR. (GAS COST = \$0.29/CCF) \$9,652
3. PAYBACK PERIOD 3 YEARS, 8 MONTHS
4. ANNUAL RETURN ON INVESTMENT 28%

ANALYSIS FOR POOL AT TYPICAL GAS COST

1. PROJECTED ANNUAL SAVINGS @ GAS COST OF \$0.50/CCF
\$16,641
2. PAYBACK PERIOD 2 YEARS, 2 MONTHS
3. ANNUAL RETURN ON INVESTMENT 48%