2023 Collegiate Turf Bowl Competition Study Guide

GCSAA would like to thank Leah Brilman, Ph.D., turfgrass product manager DLF USA, and Gwen Stahnke, Ph.D., facilitators of the Turf Bowl, for their work updating and modifying the exam each year.

The 2023 Turf Bowl Competition will be a hybrid contest comprised of an in-person exam and a virtual case study. The exam will consist of physical and visual identification of samples, and multiple-choice questions. For details on the case study, refer to the case study section of the study guide.

The study guide includes a list of resources you can use to prepare for the exam. We also recommend reaching out to local superintendents, local chapters or alumni for their help in preparing for the case study.

If you have any questions about the competition, contact Diana Kern at dkern@gcsaa.org or (785) 832-3600.

Eligibility

To participate in the GCSAA Collegiate Turf Bowl Competition, students must meet all the following eligibility criteria:

- Must be currently enrolled in a turf program or have graduated at the end of the most recent fall semester but not yet entered a graduate program
- Be an active Student member with GCSAA
- Be a registered attendee at the GCSAA Education Conference and Golf Industry Show

Important Dates

January 9, 2023: Advisors send a list of participating students and teams with the following information to Diana Kern at dkern@gcsaa.org. Onsite registration in Orlando will not be allowed.

- Student's name
- GCSAA membership number
- Email address
- If there are more than one team per school, then include the team the student will be on.

- Example: Chandler Bing, #123456, cbing@gcsaa.org, University of Kansas Team #1

January 23, 2023: Case Study PowerPoint due to Diana Kern at dkern@gcsaa.org. Late submittals will not be accepted. Details on the case study requirements are included in the Case Study section of the study guide. Note, you can turn in your case study in advance of the deadline, including before your holiday break.

January 24 – 27, 2023: Virtual grading on case studies conducted.

February 8, 2023:

- Turf Bowl Lunch/Check In 11:00 am – 1:00 pm
- Turf Bowl Competition 1 – 4 pm

February 9, 2023:

- Results announced at the GCSAA Send Off Celebration 3 – 5 pm

Area of Study

Turfgrass Identification

- Identify turf specimens by their common names or traits.
- Know common name vs. scientific name.
- For specific turfgrass species, please see Addendum 1.

Turfgrass Growth and Development

- Identify parts of the grass plant.
- Know management and environmental factors that influence growth.
- Understand turfgrass physiology and how it is influenced by management practices.
- Understand plant growth regulators – Use and influence on biology

Turfgrass Soils and Soil Fertility

- Know greens construction, particle sizes, soils and fertility.
- Know of macronutrients and micronutrients, and their influence on growth.
- Soil types and classification
- Read and interpret a soil report

Weed Identification and Control

- Identify common weeds. Note: Any turfgrasses on list can also be weeds.
- Know herbicides, what weeds they control and mode of action.
- Know the life cycle of weeds and how management influences weed growth.

- Know seed labeling for crops and weeds.
- For specific weeds, please see Addendum 2.

Turfgrass Diseases

- Identify common diseases.
- Know environmental and management conditions, and the types of diseases that the conditions favor.
- Know common fungicides.
- Know grass species corresponding to various diseases.
- For specific diseases, please see Addendum 3.

Turfgrass Mathematics

- Calculate application rates of chemicals and fertilizers.
- Know quantities of sand and seed to use.
- Know how to correctly calibrate application equipment.
- Know how to use both the Metric and English units in calculations.

Turfgrass Insects

- Identify specimens of larval and adult forms of insects that attack turf.
- Know life cycles, preferred foods, feeding methods and other characteristics important in controlling insects.
- For specific insects, please see Addendum 4.

Irrigation

- Know how to evaluate turfgrass water needs and adjust various irrigation methods and rates accordingly to ensure the efficiency and effectiveness of the irrigation system.
- Calculate water usage.
- Know the basics of using reclaimed water for irrigation.

Water Management

- Understand how turfgrasses process water, including transpiration.
- Understand water terminology
- Know the symptoms of water stress in various turfgrasses and how to remedy.
- Know the causes of pesticide and nutrient runoff and how to prevent.

Equipment Identification Section

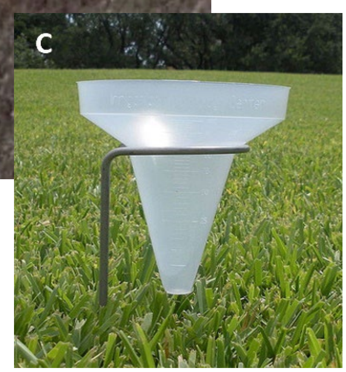
Teams will be asked answer questions on irrigation systems, including identifying components of an irrigation system and preventative maintenance practices. Study support materials are in Addendum 5.

Case Study

Scenario:

Your golf course is having problems with the irrigation system, and it is resulting in poor playing conditions (Image A).

You conduct an irrigation audit with the following catch cans (Image C) and collect the following results (Image B).



Instructions: Create a PowerPoint presentation answering the following questions. Your presentation should not exceed 20 slides. Use the notes to elaborate, when needed. Be sure to show your calculations on questions 4 and 6.

Your presentation should only include your team number. No references to your school or individual names should be made. This includes any school logos, mascots or colors.

Question 1. In addition to collecting catch can data, list at least 8 potential causes for inconsistent application of water and poor turfgrass conditions that should be inspected during the audit.

Question 2. In image 1, there are dark green circles of lush growing grass with patches of brown turfgrass areas between them. When the system was first installed, there were no patches of brown grass and the entire area was lush and green.

A. Identify the primary cause of this symptom?
B. Identify three secondary causes that may be causing the primary symptom to appear? Be sure to explain why each secondary cause will result in the primary cause.

Question 3. Inadequate head-to-head coverage is often the result of low pressure at the sprinkler head. List three potential causes for this situation.

Question 4. What is the distribution uniformity of the system? (all amounts are in ML)

24	**27**	**30**	**26**	**22**	**19**
23	**30**	**28**	**21**	**29**	**23**
19	**21**	**25**	**18**	**27**	**22**
12	**11**	**19**	**22**	**13**	**20**
9	**7**	**16**	**15**	**11**	**24**
8	**6**	**15**	**14**	**17**	**21**

Question 5. What would be the most logical explanation for the low catch-can numbers in the southwest corner (the lower left) and the apparent resulting increase of catch-can volumes as you move up and over (north and east) from those catch cans?

If you conducted this same audit on different days, could you expect different results? Why?

How could you minimize this effect?

Question 6. If the diameter of the catch-can is 5.25 inches (13.334 cm) answer the following:

1. With a 30 minute run time, calculate Precipitation Rate = in/hr ___________

2. If you want to apply a minimum of .25 inches to the entire area audited (considering your DU) how long must you run your sprinklers to achieve that goal? ____________

Question 7. List at least two viable troubleshooting strategies would you employ to determine the efficiency of the irrigation system?

Resources

The following resources, along with GCSAA's monthly publication *Golf Course Management* magazine, are recommended as study resources. The textbooks may be available through your school library, local bookstore or through the **GCSAA Store online at** https://www.gcsaastore.com/ **.**

1. **The Mathematics of Turfgrass Maintenance** (*Third Edition*) – Michael Agnew and Nick Christians
2. **Mathematics for the Green Industry: Essential Calculations for Horticulture and Landscaping Professionals -** Michael Agnew, Nancy Agnew, Ann Marie VanDerZanden and Nick Christians
3. **Turfgrass Management** (*1st Edition*) – A.J. Turgeon and J.E. Kaminski, https://turfpath.com/book/
4. **Fundamentals of Turfgrass Management** – Nick Christians
5. **Turf Management for Golf Courses** (*2nd Edition*) – James B. Beard
6. **Salt-Affected Turfgrass Sites: Assessment and Management** – R.N. Carrow and R.R. Duncan
7. **Managing Turfgrass Pests –** Thomas L. Watschke, Peter H. Dernoden and David J. Shetlar
8. **Controlling Turfgrass Pests** (*2nd Edition*) – Thomas W. Fermanian, Malcom C. Shurtleff, Roscoe Randell, Henry T. Wilkinson and Philip L. Nixon
9. **Creeping Bentgrass Management: Summer Stresses, Weeds and Selected Maladies** – Peter H. Dernoden
10. **Human Resource Management for Golf Course Superintendents, ch. 6** – Bob Milligan and Tom Maloney
11. **Superintendents Handbook of Financial Management, ch. 2, 3, 5, and 9** – Ray Schmidgall
12. **The Turf Problem Solver: Case Studies and Solutions for Environmental, Cultural and Pest Problems** – A.J. Turgeon and J.M. Jr. Vargas (Dec. 2, 2005)
13. **Identifying Turf and Weedy Grasses of the Northern United States** – D. Pedersen and T. Voight Illinois Pocket ID series University of Illinois Extension pubsplus.uiuc.edu
14. **Turfgrass Identification Tool – Purdue University Turfgrass Science Department of Agronomy** (vernation) - agry.purdue.edu/turf/tool/index.html
15. **Turfgrass Identification** (vernation)- David Gardner, The Ohio State University buckeyeturf.osu.edu/pdf/01_turfgrass_identification.pdf

16. Best Management Practices for Turfgrass Water Conservation
    commodities.caes.uga.edu/turfgrass/georgiaturf/Publicat/1650_BMP_H2O.htm
17. Best Management Practices: Where Leadership & Action Intersect – GCSAA
    https://www.gcsaa.org/environment/bmp-planning-guide
18. Golf Course Environmental Profile eifg.org/research/golf-course-environmental-profile

Addendum 1

Cool Season Grasses

Common name	**Scientific name**
1. Kentucky bluegrass	*Poa pratensis*
2. Perennial ryegrass	*Lolium perenne*
3. Tall fescue	*Festuca arundinacea = Schedonorus arundinaceus = Lolium arundinaceum*
4. Hard fescue	*Festuca brevipila (F. trachyphylla)*
5. Chewings fescue	*Festuca rubra* ssp. *commutata* (ssp. *fallax)*
6. Creeping bentgrass	*Agrostis stolonifera*
7. Colonial bentgrass	*Agrostis capillaris*
8. Strong creeping red fescue	*Festuca rubra* ssp. *rubra*
9. Slender creeping red fescue	*Festuca rubra ssp. littoralis*
10. Velvet bentgrass	*Agrostis canina*
11. Rough bluegrass	*Poa trivialis*
12. Annual bluegrass	*Poa annua*
13. Annual ryegrass	*Lolium multiflorum*

Warm Season grasses

14. Japanese / Korean lawngrass	*Zoysia japonica*
15. Manilla grass	*Zoysia matrella*
16. Hybrid bermudagrass	*Cynodon dactylon* X *C. transvaalensis*
17. Common bermudagrass	*Cynodon dactylon*
18. Centipedegrass	*Eremechloa ophiuroides*
19. Seashore paspalum	*Paspalum vaginatum*
20. Buffalograss	*Bouteloua dactyloides*
21. St. Augustinegrass	*Stenotaphrum secundatum*

22. Kikuyugrass	*Pennisetum clandestinum*
23. Bahiagrass	*Paspalum notatum*
24. Carpetgrass	*Axonopus affinis*

Addendum 2

Weeds

Alkaligrass	*Puccinella distans*
Barnyardgrass / Watergrass	*Echinochloa crus-galli*
Bedstraw / Catchweed	*Galium aparine*
Bindweed, Field	*Convolvulus arvensis*
Brassbuttons, Souther	*Cotula australis*
Buttonweed, Virginia	*Diodia virginia*
Carpetweed	*Mollugo verticillata*
Carrot, Wild	*Daucus carota*
Chess, Soft	*Bromus hordeaceus*
Chickweed, Common	*Stellaria media*
Chickweed, Mouseear	*Cerastium vulgatum*
Chicory	*Cichorium intybus*
Clover, White	*Trifolium repens*
Crabgrass, Hairy (Large)	*Digitaria sanguinalis*
Crabgrass, Smooth	*Digitaria ischaemum*
Cudweed, purple	*Gnaphalium purpureum*
Dallisgrass (smooth paspalum)	*Paspalum dilatatum*
Dandelion, False /spotted catsear	*Hypochoeris radicata*
Dandelion	*Taraxacum officinale*
Dichondra	*Dichondra repens*
Dock, Curly	*Rumex crispus*
Downy Brome / cheatgrass	*Bromus tectorum*
English Daisy	*Bellis perennis*
Foxtail, Yellow (pigeon / bristle grass)	*Setaria glauca (pumilla ssp pumilla)*
Foxtail , Green	*Setaria viridis*
Garlic , Wild	*Allium vineale*
Geranium, Carolina / dovefoot	*Geranium ssp.*
Goosegrass/Silver Crab/ Crowfoot	*Elusine indica*
Ground Ivy (Creeping Charlie/Jenny)	*Glechoma hederacea*
Hawkweed	*Hieracium pratense*
Henbit	*Lamium amplexicaule*
Johnsongrass	*Sorghum halapense*
Kikuyugrass	*Pennisetum clandestinum*
Knotweed, Prostrate / Common	*Polygonum aviculare*
Kochia	*Kochia scoparia*

Kyllinga, Annual / Fragrant	*Kyllinga odorata*
Kyllinga, Green / Perennial	*Kyllinga brevifolia*
Lambsquarter	*Chenopodium album*
Lettuce, Prickly	*Lactuca serriola*
Mallow, Common	*Malva neglecta*
Medic, Black	*Medicago lupulina*
Moss, silvery thread	*Bryum argenteum*
Mullein, Common	*Verbascum thapsus*
Nimblewill	*Muhlenbergia schreberi*
Nutsedge, Purple	*Cyperus rotundus*
Nutsedge, Yellow	*Cyperus esculentus*
Oats, Wild	*Avena fatua*
Orchardgrass	*Dactylis glomerata*
Pearlwort	*Sagina apetala (procumbens)*
Pennywort / dollarweed	*Hydrocotyle umbellate*
Peppergrass / pepperweed	*Lepidium virginicum*
Pigweed, Prostrate	*Amaranthus blitoides*
Pineapple Weed / wild chamomile	*Matricaria discoidea*
Plaintain, Broadleaf	*Plantago major*
Plantain, Buckhorn / Narrowleaf	*Plantago lanceolata*
Puncture Vine / goatshead	*Tribulus terrestris*
Purslane, common	*Portulaca oleracea*
Quackgrass	*Elytrigia repens*
Rattail fescue	*Vulpia myuros*
Redtop	*Agrostis gigantean (alba)*
Salsify, Western	*Tragopogon dubius*
Sandbur/ grassbur	*Cenchrus incertus*
Sedge, Annual	*Cyperus compressus*
Shepherd’s Purse	*Capsella bursa-pastoris*
Signalgrass	*Urochloa subquadripara*
Smartweed, Spotted (Ladysthumb)	*Polygonum persicaria*
Smutgrass	*Sporobolus indicus*
Sorrell, Red / Sheeps	*Rumex acetosella*
Speedwell, creeping	*Veronica filiformis*
Spurge, Prostrate / Spotted	*Chamaesyce maculata (Euphorbia)*
Star of Bethlehem	*Ornithogalum umbellatum*
Strawberry, Wild	*Fragaria virginiana*
Swinecress	*Coronopus didymus*
Timothy	*Phleum pratense*
Thistle, Bull	*Cirsium vulgare*
Thistle, Canada	*Cirsium arvense*

Thistle, Musk	*Carduus nutans*
Torpedograss	*Panicum repens*
Velvetgrass, German	*Holcus mollis*
Violet	*Viola ssp.*
Woodsorrel, Creeping	*Oxalis corniculata*
Woodsorrel, Yellow (Oxalis)	*Oxalis stricta*
Yarrow	*Achillea millefolium*
Yellowcress	*Rorippa palustris*

Addendum 3

Bacterial Diseases

Bacterial wilt	*Xanthomonas translucens*
Bacterial etiolation and decline	*Acidovorax avenae*

Fungal Diseases

Anthracnose	*Colletotrichum cereale, C. eremochloae*
Ascochyta leaf blight	*Ascochyta avenae*
Bermudagrass decline	See Root decline of warm-season grasses
Blister smut	*Jamesdicksonia dactylidis*
Brown patch (C3) & large patch (C4)	*Rhizoctonia solani*
Brown ring patch	*Waitea circinata* var. *circinata*
Brown stripe	*Mycosphaerella recutita*
Cladosporium eyespot	*Cladosporium phlei*
Copper spot	*Gloeocercospora sorghi*
Coprinus snow mold	*Coprinopsis psychromorbida*
Crown rust	*Puccinia coronata*
Curvularia blight	multiple *Curvularia sp.*
Dead spot	*Ophiosphaerella agrostis*
Dollar spot	*Clarireedia* is new genus *Clarireedia homeocarpa* on *Festuca rubra,* UK only *Clarireedia bennettii* on mostly cool season grasses, UK, Netherlands, USA *Clarireedia monteithiana* on Warm-season grasses; found worldwide *Clarireedia jacksonii* on cool-season grasses; found worldwide
Drechslera leaf spots and melting-out	multiple *Drechslera* and *Marielliottia sp.*
Endophytic fungi	*Neotyphodium coenophialum, N. lolii, Epichloe typhina*
Fairy ring	Species of Agraricales and Gastromycetales, mostly in the genera *Agaricus, Calvatia, Chlorophyllum, Clitocybe, Lepiota,*

	Lycoperdon, Marasmius, Scleroderma, and *Tricholoma*.
Flag smut	*Urocystis agropyri*
Gray leaf spot	*Pyricularia grisea*
Gray snow mold	*Typhula incarnata*
Leaf and sheath spot	*Waitea circinata var. zeae, W. circinata var. oryzae*
Leaf rust	*Puccinia brachypodii*
Leptosphaerulina leaf blight	*Leptosphaerulina trifolii*
Mastigosporium leaf spot (leaf fleck)	*Mastigosporium rubricosum*
Microdochium patch	*Microdochium nivale*
Necrotic ring spot	*Ophiosphaerella korrae*
Phyllosticta leaf blight	Multiple species of *Phyllosticta* and *Guignardia*
Physoderma leaf spot and leaf streak	*Physoderma graminis*
Pink patch and cream leaf blight	*Limonomyces roseipellis*
Pink snow mold	See Microdochium patch
Powdery mildew	*Blumeria graminis*
Pythium foliar blight	*Pythium aphanidermatum*, *P. graminicola*, *P. ultimum, Several other Pythium species*
Pythium root and crown rot	*Pythium aristosporum*, *P*. *arrhenomanes*, *Pythium volutum, several other Pythium species*
Pythium root dysfunction:	*Pythium volutum*, *P. arrhenomanes*, *P. aristosporum, several other Pythium species*
Rapid blight	*Labyrinthula terrestris*
Red thread	*Laetisaria fuciformis*
Root decline of warm-season grasses	*Gaeumannomyces graminis* var. *graminis, Magnaporthiopsis incrustans, G. wongoonoo*
Septoria leaf spot	several *Septoria* species
Snow scald	*Sclerotinia borealis*
Southern blight	*Athelia rolfsii*
Speckled snow mold	*Typhula ishikariensis*
Spring dead spot	*Ophiosphaerella narmari, O. korrae, O. herpotricha*
Stem rust	*Puccinia graminis*
Stripe rust	*Puccinia striiformis*
Stripe smut	*Ustilago striiformis*
Summer patch	*Magnaporthiopsis poae*
Take-all patch	*Gaeumannomyces graminis*
Tar spot	*Phyllachora* spp.
Thatch collapse	*Sphaerobollus stellatus*
Yellow patch	*Rhizoctonia cerealis*
Yellow tuft	*Sclerophthora macrospora* .
Yellow ring	*Trechispora alnicola*

Nematodes, Parasitic

Awl: *Dolichodorus* spp. Cobb
Cyst: *Heterodera* spp. Schmidt
Dagger: *Xiphinema* spp. Cobb
Lance: *Hoplolaimus* spp. Daday
Lesion: *Pratylenchus* spp. Filipjev
Needle: *Longidorus* spp. (Micoletzky) Thorne & Swanger
Pin: Paratylenchus spp.
Pseudo-root knot: *Hypsoperine* spp. Sledge & Golden
Ring: Criconemella, Criconemoides, *Macroposthonia,* and *Mesocriconema* spp.
Root gall: *Subanguina* spp.
Root knot: *Meloidogyne* spp. Goeldi
Sheath: *Hemicycliophora* spp.
Sheathoid: *Hemicriconemoides* spp.
Spiral: *Helicotylenchus* spp. Steiner
Sting: *Belonolaimus* spp. Steiner
Stubby root: *Paratrichodorus* and *Trichodorus* spp.

Stylet or stunt: *Tylenchorhynchus* spp. Cobb

Miscellaneous Diseases or Disorders

Black Layer: A
Anaerobic soil plus blue-green algae and/or sulfate-reducing bacteria
Slime Molds (superficial, not pathogenic):
Mucilago crustacea
: *Didymium squamulosum*
: *Physarum cinereum*.
: Species of *Physarum* and *Fuligo*

Addendum 4:

Insects

Annual Bluegrass Weevil

Billbugs

- bluegrass billbug
- hunting billbug

Black Turfgrass Ataenius

Chinchbugs

- hairy chinchbug

- southern chinchbug

Craneflies

- European cranefly *(Tipula paludosa)*
- "common" cranefly *(Tipula oleraceae)*

Caterpillars and adults

- armyworm
- black cutworm
- fall armyworm
- winter cutworm

Mole Crickets

- southern mole cricket
- tawny mole cricket

Red Imported Fire Ant

Turfgrass Ant

White Grubs and Adult Beetles

- Asiatic garden beetle
- European chafer
- Japanese beetle
- masked chafer (southern)
- masked chafer (northern)
- oriental beetle

Wasps

- Scoliid
- Cicada Killers
- yellow jacket
- Paper wasp

Beneficials

Honey bees

Assassin bugs

Ground beetle

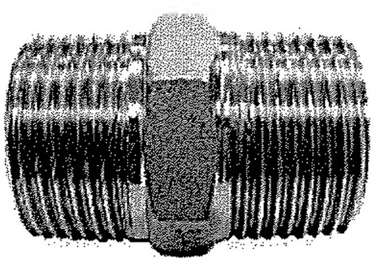
Lacewing

Praying Mantis

Addendum 5:
For Case Study and Equipment Section

A Short Article on Nipple as Pipe Fitting

In piping, a nipple is a fitting, consisting of a short piece of pipe, usually provided with a male pipe thread at each end, for connecting two other female threaded fittings or pipes. Pipe Nipples are commonly used as adapters from one connection type to another. Pipe nipples are mainly used in low-pressure piping systems.



www.theprocesspiping.com

Pipe nipples are manufactured by cutting a specified length of pipe and applying the desired end connections. The pipe nipple dimensions and material follow from pipe specifications. Similar to pipe, pipe nipples also come in either a seamless or welded construction.

When ordering pipe nipples, the following properties must be specified:

- Diameter
- Length
- Schedule
- Material
- End Connections

The length of pipe nipple is usually specified by the overall length including threads. Pipe Nipples can come in any specified length, but most commonly range between close to 12". A close pipe nipple is the shortest piece of pipe necessary to allow for fully threaded end connections, where there is no smooth surface between threads.

Types of Pipe Nipple

There are several different types of pipe nipples in common use. A short list includes:

- Close Nipple / Running Nipple
- Hexagonal Nipple
- Reducing Nipple / Unequal Nipple
- Hose Nipple
- Welding Nipple

Close Nipple / Running Nipple

In its most basic form, a pipe nipple is a short length of pipe with male pipe threads at both ends for connecting other fittings. Generally there is a short distance of unthreaded pipe between the two threaded ends, depending on how far apart you need the attached fittings to be. When there is no unthreaded pipe between the two connecting ends, the pipe nipple is called a **"close nipple"** or a "**running nipple"**. In that case, connected fittings come close to touching one another and very little of the nipple can be seen.

Close nipples are difficult to work with. A close nipple can only be unscrewed by gripping one threaded end with a pipe wrench which will damage the threads and necessitate replacing the nipple, or by using a specialty tool known as a nipple wrench which grips the inside of the pipe, leaving the threads undamaged.

Hexagonal Nipple

In pipe nipples where there is a little space between both the threaded ends, there may have a hexagonal section in the center for a wrench to grasp the nipple. These nipples are called as **"hexagonal nipple"**. This hexagonal section in the middle functions like a nut that can be gripped by a normal wrench, providing a greater mechanical advantage than normal rounded pipe nipple. A hexagonal nipple with more distance between the threaded ends is called a **"long hex nipple"**.

Reducing Nipple / Unequal Nipple

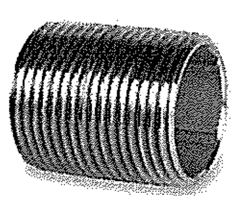
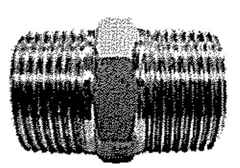
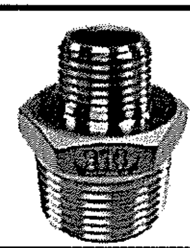
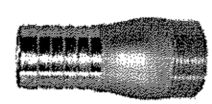
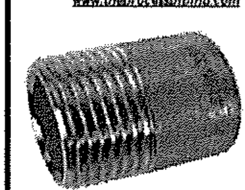
For ping systems which require a change in pipe dimension, **“reducing nipple”** or **“unequal nipple”** is used. Reducing nipple takes a female fitting with a larger connection and attaches it to a smaller one. Care should be taken when using these parts since a reduction in pipe diameter can mean more pressure and greater flow rate in the smaller pipe/fitting.

Hose Nipple

For piping systems which require pipe connection to tubing, **“hose nipple”** is used. Hose nipple features a male threaded connection on one end and a hose barb on the other end. The hose barb may be the same size as the pipe connection or it may be of reduced size.

Welding Nipple

For piping systems which requires to be connected to welded pipes or fittings, “welding nipple” is used. Welding nipple has a threaded connection on one end and normal cut pipe at the other end. The unthreaded end of the pipe provides more surface area for the use of welding materials to make the stronger connection. One main benefit of welding nipple is that once the unthreaded end is connected, connecting pipes or other fittings to the threaded end becomes much more easy.

				
Close Nipple	Hexagonal Nipple	Reducing Nipple	Hose Nipple	Welding Nipple

Pipe Nipple End Connections

The end connections need to be specified by the customer as well;

Plain Both Ends (PBE), Threaded Both Ends (TBE), Beveled Both Ends (BBE), Threaded One End (TOE), Beveled One End (BOE), Plain One End (POE) or a combination thereof, depending on the ends of the piping system into which the pipe nipple will be fitted.

A **Plain Both Ends (PBE)** pipe nipple, has both the ends as plain ends, with no thread, typically used to fit a socket weld connection.
A **Threaded Both Ends (TBE)** pipe nipple has both the ends as threaded ends and used to fit female threaded connections.
A **Beveled Both Ends (BBE)** pipe nipple has both the ends as bevel ends and is used for welding purposes similar to a buttweld fitting.

Conducting an Irrigation Audit

Irrigation audits are performed on sports fields to check the operation and efficiency of the irrigation system and to make sure all areas are receiving the appropriate amounts of water. When an irrigation audit is conducted properly, it can provide information to improve irrigation efficiency, reduce water costs, lessen turfgrass plant damage, significantly decrease the likelihood of water runoff, and in some cases, help convince decision makers that a new irrigation system may be needed. An irrigation audit measures the precipitation rate and the uniformity of water that is being applied. The audit process documents irrigation issues in a qualitative way that is valuable when used as a benchmark for the operation of the irrigation system.

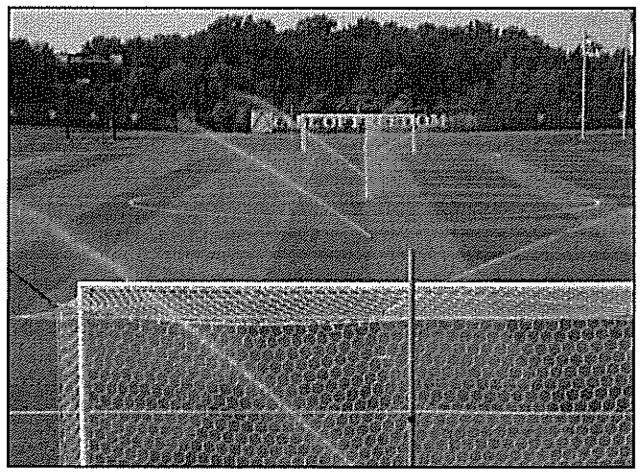


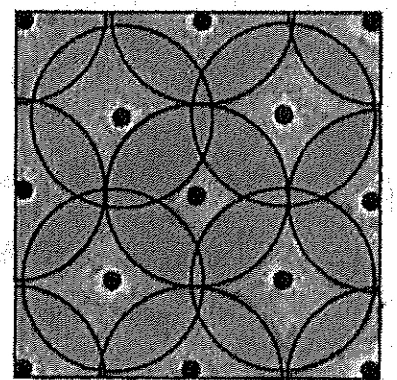
Photo courtesy of Jerad Minnick

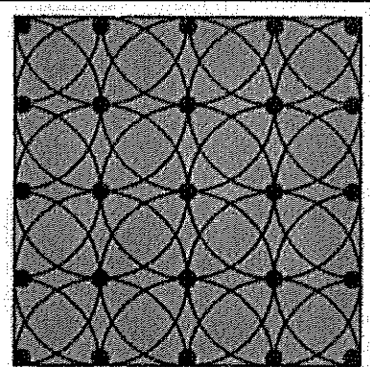
Pre-Audit

Before conducting an irrigation audit, the irrigation system should be in optimal working condition. Check that the system complies with local codes, identify operational defects or deficiencies, and make repairs to the system. Repairing and adjusting malfunctioning irrigation components will make a huge improvement in the efficiency of the system and decrease water consumption. Common causes of breaks or inconsistencies in the system that contribute to water waste include:

- Tree roots
- Sprinkler heads that do not turn due to wear
- Heads that turn, but don't follow a preset pattern due to misalignment
- Broken or missing sprinkler heads
- Incorrect or mismatched nozzles
- Mixed zones (for example: full circle and half circle rotors utilizing nozzles with the same precipitation rate)
- Leaking heads and pipe connections
- Bent risers due to damage from a mower or other vehicle which results in water being delivered at an incorrect angle
- Risers that do not rise above the turfgrass
- Geysers from a missing nozzle, vandalism, or age
- Orifices clogged due to sand and other debris
- Sunken sprinkler heads

- Sprinkler heads spaced too far apart or too close together
- Insufficient or excessive operating pressure





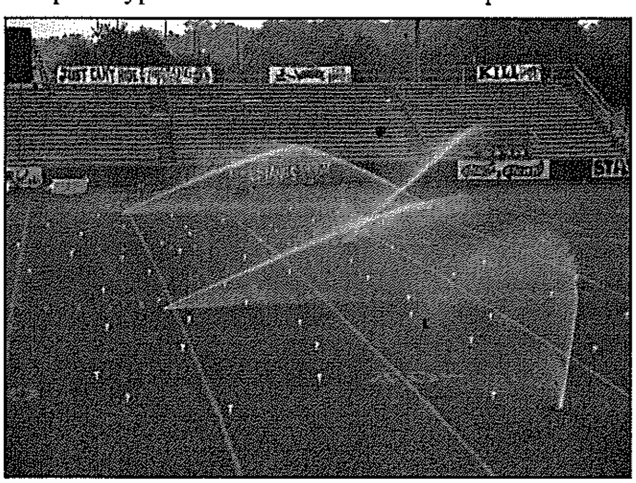
Low pressure and poor coverage (left) compared to correct pressure and full coverage (right) – Photos courtesy of Jeff Gilbert

Use Worksheet #1 – Site Inspection at the end of the bulletin to assist with identifying irrigation problems that need to be corrected.

In some cases, it may be better to conduct the audit "as-is" with the irrigation system. This is dependent on if the manager is trying to prove or show inadequacy and can help in the effort to install a new irrigation system or update an existing system.

Irrigation Audit

Conducting an irrigation audit on the entire irrigation system is recommended; especially if the site has never undergone an audit. However, depending on goals, you may choose to engage in linking. Linking uses information from one station or zone and applies it to another, and can be used when there are a large number of sprinkler zones that are identical. For example, zones may have the same sprinkler head, nozzles, spacing, operating pressure, or similar soil and plant types. Catch device tests can be performed on one-third to one-half of the sprinkler zones to get an average value that could be applied to all sprinkler zones that are identical. If you choose to use linking, be sure to audit a variety of areas. For example, select areas where you are having trouble, areas that perform well, and average areas to determine how well your irrigation system is performing. Be sure to audit problematic features from an irrigation standpoint, such as sprinkler spacing, nozzle pressure, or sunken or tilted sprinkler heads. Linking can be an effective practice, however, it is suggested that every zone eventually receives an audit.



Catch can testing – Photo courtesy of Jeff Gilbert

The audit should reflect normal operating conditions. If normal operating conditions occur at odd hours, some assessment of the impact of these conditions should be made during the tested conditions.

Conducting an Irrigation Audit

The most accurate determination of precipitation rate and distribution uniformity is achieved by conducting catch can tests. Catch can tests measure the amount of water that actually hits the ground at various points on each field or landscape feature. Catch devices are laid out on a set spacing to collect water for a predetermined amount of time. The amount of water collected is measured to calculate distribution uniformity and net precipitation rate of the irrigation system. For best results, all catch devices must be uniform in size and shape. Larger collectors give better repeatable results. It is important to conduct catch can tests for each individual zone or station of an irrigation system. Using catch cans is the best way to determine how well or how poorly the irrigation system applies water.

Steps to Perform a Catch Can Test:

Step 1: Obtain the materials needed to conduct the audit. You may be able to obtain an Irrigation Audit Kit from your local Cooperative Extension or a local commercial company. Otherwise, collect the following items to perform an irrigation audit:

- Flags
- Tape measure
- Catch devices
- Stopwatch
- Ruler with inches/centimeter
- Nozzle pressure gauge
- Graduated cylinder
- Calculator
- Worksheets (provided at the end of the bulletin)

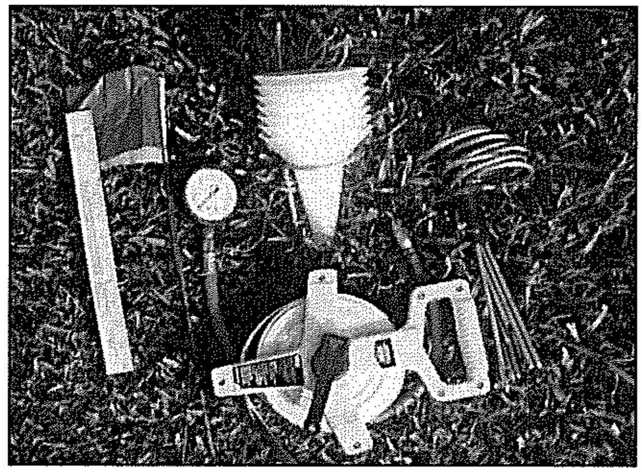


Photo courtesy of Jeff Gilbert

Step 2: Turn on the irrigation system one zone at a time to locate and mark sprinkler heads. Use Worksheet #2 – Test Area Data and Map provided at the end of the bulletin to help map out the area being audited.

Step 3: Starting with Zone 1, lay out catch devices only on the turfgrass area covered by Zone 1. Catch devices should be placed in a grid-like pattern throughout the zone to achieve an accurate representation of sprinkler performance. Be sure not to place catch devices too close to sprinkler heads to avoid altering spray patterns. A minimum of 24 catch devices should be used. Minimum catchment device spacing:

- Fixed spray sprinklers – near a head (within 2-3 feet) and half-way between the heads.
- Rotor sprinkler heads spaced less than 40 feet on center - near a head (within 2-3 feet) and every one-third of the distance between the heads.
- Rotor heads spaced greater than 40 feet on center - near a head (within 2-3 feet) and every one-fourth of the distance between the heads.

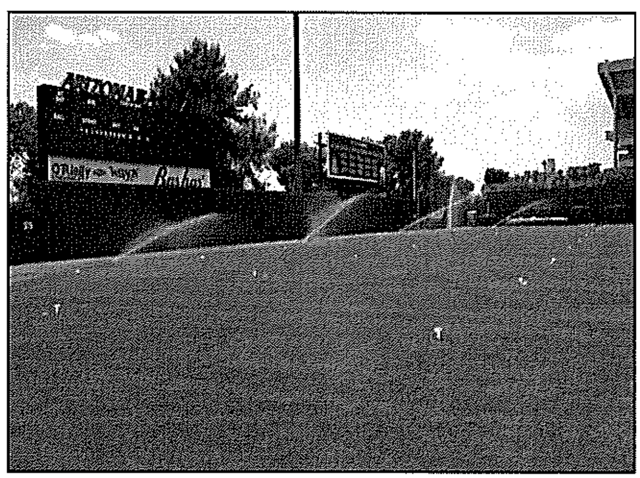


Photo courtesy of Jeff Gilbert

- The catchments along the edge of the zones should be placed 12 to 24 inches in from the edge.
- On unusual or irregularly shaped areas (such as a baseball infield) that utilizes rotor sprinklers, set up a uniform grid

of catch devices that is 10-20 feet on center spacing. Areas that utilize spray sprinklers (such as curvilinear areas without defined rows of sprinklers) should be set up as a uniform grid of catch devices that are 5-8 feet on center spacing.

Step 4: Turn on Zone 1 and allow water to partially fill catch devices. Record the number of minutes the zone is allowed to operate. Test run times must be consistent and appropriate for the sprinkler type and arc. While the zone is running, check the effectiveness of repairs made to the irrigation system. Take notes such as "west head not turning properly", "riser may have been driven over", or "possible leak". If problems exist, repair or make appropriate adjustments. Use Worksheet #1 – Site Inspection at the end of the bulletin to identify additional problems that may need to be corrected.

Catch device – Photo courtesy of Jeff Gilbert

Step 5: While each zone is running, record and document the following information about the irrigation system and performance (use the worksheets provided at the end of the bulletin to help document information):

- Date and time of testing
- Weather conditions
- Soil types and rootzone depths
- Approximate catchment device locations outlined on a map or grid
- Catchment readings
- Test run time in minutes
- Meter readings (if available)
- Pressure readings with locations. Pressure tests should be conducted at normal operating conditions at the sprinkler using the appropriate pressure testing device at the beginning and end of each zone audited. Sprinkler heads are designed to operate within specific operating pressures and head spacing. A pitot tube can be used to measure the sprinkler's operating pressure as the water exits the sprinkler. The tube is placed in the stream of water just as it is exiting the sprinkler. The operating pressure can be compared to the operating pressure recommended by the manufacturer.
- Wind speed readings. Wind speed should be 5 mph or less during the audit. Monitor and record wind speed every 5 minutes during the audit.

Measure operating pressure – Photo courtesy of Jeff Gilbert

Step 6: Once the system has run for the predetermined time period, measure the amount of water collected in each catch device. Record values on Worksheet #3 – DU and PR Calculations provided at the end of this bulletin. Catchments for a test area should be documented to facilitate repeatability.

Step 7: Repeat steps 1-5 for each remaining zone in the turfgrass area. When the test area contains multiple stations, the test run times for each station or zone must be adjusted to achieve a matched precipitation rate across the test area. Ideally, each catch device should contain approximately the same amount of water. The goal is to achieve uniform distribution. No irrigation system is perfect, but it is important to get close in order to reduce turfgrass and irrigation system problems.

Post-Audit

Once the audit has been completed, it is time to calculate the distribution uniformity and precipitation rate based on the data collected using Worksheet #3.

Calculating Precipitation Rate

Depending on the type of catch device used, precipitation rate can be calculated by using milliliters or inches. If catch cans do not have parallel sides, it is best to measure volume (in mL, which is equivalent to cm^3) and determine depth by dividing volume by area (in cm^2) of the containers opening.

Calculating Precipitation Rate Using mL:

Measure catch volume: ________ mL (mL converts directly to cm^3)

Calculate area of catch device opening: $\dfrac{\_\_\_\_\_\_\_\_ \text{ mL}}{\text{Area } (\pi r^2)} = \_\_\_\_\_\_\_\_ \text{ cm}^2$

$$\text{cm} = \frac{\_\_\_\_\_\_\_\_ \text{ cm}^3}{\_\_\_\_\_\_\_\_ \text{ cm}^2}$$

$$\text{inches of water in catch device} = \frac{\_\_\_\_\_\_\_ \text{ cm}}{2.54 \text{ cm}}$$

$$\text{PR} = \frac{\_\_\_\_\_\_\_\_ \text{ inches of water in catch device}}{\_\_\_\_\_\_\_\_ \text{ minutes run time}} \times 60$$

PRECIPITATION RATE = ________ in/hr

If using catch cans with parallel sides, inches per hour can be found by measuring the depth of water captured in the cans.

Calculating Precipitation Rate Using Inches:

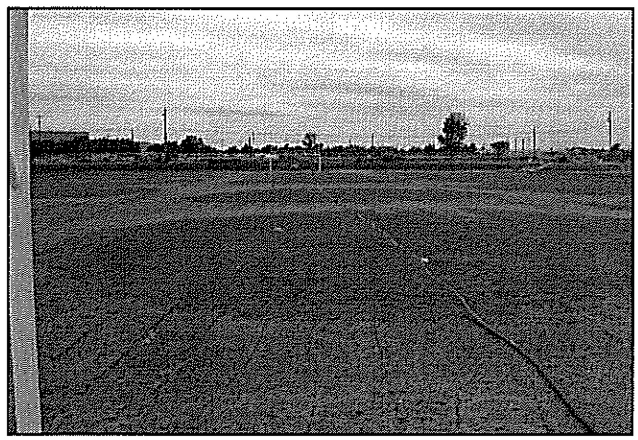
$$PR = \frac{\text{Average Catch Can Depth}}{\text{Testing Run Time}}$$

$$PR = \left[\frac{(\_\_\_\_\_\_ \text{ inches})}{(\_\_\_\_\_\_ \text{ minutes})} \right] \times 60$$

PRECIPITATION RATE = ________ in/hr

Calculating Distribution Uniformity

The most common measure of distribution uniformity is the Low Quarter Distribution Uniformity. This is a measure of the average of the lowest quarter of catchment samples, divided by the average of all catchment samples. A higher distribution uniformity indicates a better performing irrigation system. If all catchment samples are equal, the distribution uniformity is 100%. There is no universal value of distribution uniformity for satisfactory system performance, but generally a value greater than 70% is considered acceptable. The lower the distribution uniformity, the less efficient the distribution, which means more water must be applied to meet the minimum requirement.



Make sure to maximize distribution uniformity – Photo courtesy of Jeff Gilbert

$$\text{DU (of lower quarter)} = \frac{\text{Avg Catch in lower quarter}}{\text{Avg Catch Overall}}$$

$$DU = \frac{\_\_\_\_\_\_\_\_ \text{ mL}}{\_\_\_\_\_\_\_\_ \text{ mL}}$$

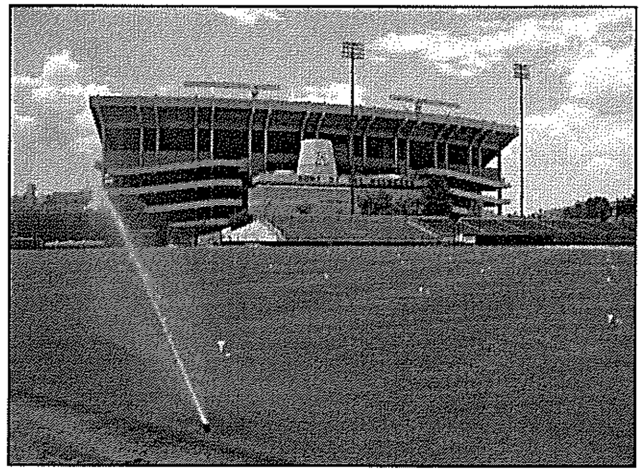
DISTRIBUTION UNIFORMITY (DU) = ________

Distribution uniformity is useful when determining the total watering requirement during irrigation scheduling.

For example: An irrigator does not want to apply less than one inch of water to an area. If the distribution uniformity is 75%, total amount of water to be applied would be the desired amount of water divided by the distribution uniformity (1 inch / 0.75). In this case, the required irrigation would be 1.33 inches of water. Keep in mind that applying at least 1 inch of water to the entire area will result in over irrigating some areas.

Applying the Results

Irrigation audits are extremely beneficial when it comes to determining the irrigation schedule for turfgrass areas. When and how long to irrigate are often based on assumptions and generalizations in regards to sprinkler system performance and plant-water requirements. Audits provide data that allows irrigation schedules to be customized to both the irrigation system, the plants, and watering based on evapotranspiration. Rather than using long time recommendations such as "15 minutes, 3 times per week", run times can be adjusted for individual zones based on the measured precipitation rate and distribution uniformity.


Catch can testing – Photo courtesy of Jeff Gilbert

In addition to applying the results of an audit to an irrigation program, plant and soil factors must be taken into consideration. Determining when to irrigate should be based on the depth of plant roots and the type of soil rootzone. For example, turfgrass with a shallow rootzone growing in a predominantly sandy soil will require more frequent irrigation. In comparison, turfgrass with a deep rootzone growing in predominantly loam soil will require less frequent irrigation. Plant-water requirements also vary significantly depending on the variety of plant species, maintenance practices, microclimates, climate trends, and rainfall patterns. Be sure to assess plant-water needs, rootzone depth, and type of rootzone when determining frequency and amount of water to be applied in an irrigation program.

To determine how much water needs to be applied during each irrigation event, convert to zone run time:

$$\text{Run Time per Irrigation Cycle} = \frac{\text{Target Irrigation Depth}}{\text{Zone Precipitation Rate}}$$

$$\text{Run Time \_\_\_\_\_\_\_\_ minutes} = \frac{\text{\_\_\_\_\_\_\_\_ inches}}{\text{\_\_\_\_\_\_\_\_ inches/hour}} \times 60$$

Run Time per Irrigation Cycle = ________

Conclusion

An irrigation audit will provide insight into the operation of your irrigation system and help you determine how to improve its efficiency. Keeping accurate and up-to-date records throughout the year will help during the auditing process. Records should include water use and weather information such as rainfall amounts, evapotranspiration rates, and high temperatures. Information about the irrigation system such as controllers, number of irrigated acres, system improvements, head locations, spacing, operating pressure, sprinkler make, model, and nozzle sizes should also be recorded.

Conducting annual audits and making simple repairs and adjustments to malfunctioning irrigation components will make a huge improvement in the efficiency of the system and decrease water consumption. All systems require periodic maintenance and repairs to be sure the system is operating efficiently and minimizing water waste.

Conversions

1 inch = 25mm
1 $inch^2 = 6.45\ cm^2$
1 $inch^3 = 16.387064$ mL
1 US gallon = 5/8 of 1 Imperial gallon
1 Imperial gallon = 4.54 liters
1 US gallon = 3.785 liters

Resources:
Contributions from STMA Information Outreach Committee
Irrigation Association – Irrigation Audit Guidelines - http://www.irrigation.org/Resources/Audit_Guidelines.aspx
Irrigation Association SuperTip – Superintendent Magazine - http://www.superintendentmagazine.com/article-9132.aspx
Irrigation Audits: Pinpoint Problems - John Fech - http://www.turf-digital.com/mar2012/North/0/0#&pageSet=14
General Landscape Irrigation Audit Procedures – North Carolina State University - http://www.turffiles.ncsu.edu/pdffiles/004509/General_Landscape_Irrigation_Audit_Procedures.pdf
Water Reduction 101 – An Audit Competition – Michael Carr and Gordon Kunkle – 2011 STMA Conference Presentation - http://www.stma.org/sites/stma/files/Conference/2012_Conference/Carr.pdf

WORKSHEET #1 – SITE INSPECTION

Site Name: ______________________________

Audit Date/Time: ______________________ **Current Weather Conditions** ______________________

Site inspection is only necessary on the zones being audited. Record the number of defects for each sprinkler problem or check mark for zone problems; leave blank if no problem exists.

Controller Identification

Station Number:										
Turfgrass Species/ Cultivar										
Sprinkler Type - Manufacturer - Model Name/Number										
Observed Problems:										
Valve Malfunctions										
Low Pressure										
High Pressure										
Tilted Sprinklers										
Spray Deflection										
Sunken Sprinklers										
Plugged Equipment										
Arc Misalignment										
Low Sprinkler Drainage										
Leaky Seals or Fittings										
Lateral or Drip Line Leaks										
Missing or Broken Heads										
Slow Drainage or Ponding										
Compaction/ Thatch/Runoff										
Notes and Comments:										

*Adapted from Golf Audit Worksheets available from the Irrigation Association

WORKSHEET #2 – TEST AREA DATA AND MAP

Site Name: ______________________________

Audit Date/Time: ______________________________

Station #: ______________________________

Controller ______________________________

Run time ______________________________ min.

Pressure ______________________________ psi

Meter Reading ______________________________

Wind Speed: ______________________________ mph

Rootzone Depth ______________________________ inches

Soil Type

- ☐ Clay
- ☐ Loam
- ☐ Sand

Plant Material

- ☐ Cool-season turfgrass
- ☐ Warm-season turfgrass
- ☐ Ground cover
- ☐ Shrubs

Zone

- ☐ Overlap
- ☐ Stand-alone

Indicate north and ALL audit area dimensions

O = SPRINKLER – Record the location of each sprinkler and sprinkler spacing.

X = CATCH DEVICE – Record the location of each catch device and catch amount.

*Adapted from Golf Audit Worksheets available from the Irrigation Association

WORKSHEET #3 – DU AND PR CALCULATIONS

Site Name: ____________________

Audit Date/Time: ____________________

All values and calculations must be completed for Worksheet #3.

Run time ____________________ min.

Catchment Type ____________________

Catchment Device Area ____________ sq. in.

1) Record ALL catch device values.

2) Circle ALL values used to calculate lower quarter.

Can #1 ____	#11 ____	#21 ____	#31 ____	#41 ____	#51 ____	#61 ____
Can #2 ____	#12 ____	#22 ____	#32 ____	#42 ____	#52 ____	#62 ____
Can #3 ____	#13 ____	#23 ____	#33 ____	#43 ____	#53 ____	#63 ____
Can #4 ____	#14 ____	#24 ____	#34 ____	#44 ____	#54 ____	#64 ____
Can #5 ____	#15 ____	#25 ____	#35 ____	#45 ____	#55 ____	#65 ____
Can #6 ____	#16 ____	#26 ____	#36 ____	#46 ____	#56 ____	#66 ____
Can #7 ____	#17 ____	#27 ____	#37 ____	#47 ____	#57 ____	#67 ____
Can #8 ____	#18 ____	#28 ____	#38 ____	#48 ____	#58 ____	#68 ____
Can #9 ____	#19 ____	#29 ____	#39 ____	#49 ____	#59 ____	#69 ____
Can#10 ____	#20 ____	#30 ____	#40 ____	#50 ____	#60 ____	#70 ____
Column Subtotals						
______	______	______	______	______	______	______

TOTAL CATCH ____________________ mL

TOTAL CATCH IN LOWER QUARTER ________ mL

AVERAGE CATCH ____________________ mL

AVERAGE CATCH IN LOWER QUARTER ______ mL

*Adapted from Golf Audit Worksheets available from the Irrigation Association

WORKSHEET #3 – DU AND PR CALCULATIONS

Site Name: ____________________

Audit Date/Time: ____________________

Calculate Precipitation Rate (PR) (using mL)

Measure catch volume: ________ mL (mL converts directly to cm^3)

Calculate area of catch device opening: $\frac{\_\_\_\_\_\_\_\_ \text{ mL}}{\text{Area } (\pi r^2)} = \_\_\_\_\_\_\_\_ \text{ cm}^2$

$$\text{cm} = \frac{\_\_\_\_\_\_\_\_ \text{ cm}^3}{\_\_\_\_\_\_\_\_ \text{ cm}^2}$$

$$\text{inches of water in catch device} = \frac{\_\_\_\_\_\_\_ \text{ cm}}{2.54 \text{ cm}}$$

$$\text{PR} = \frac{\_\_\_\_\_\_\_\_ \text{ inches of water in catch device}}{\_\_\_\_\_\_\_\_ \text{ minutes run time}} \times 60$$

PRECIPITATION RATE = ________ in/hr

Calculate Distribution Uniformity (DU)

$$\text{DU (of lower quarter)} = \frac{\text{Avg Catch in lower quarter}}{\text{Avg Catch Overall}}$$

$$\text{DU} = \frac{\_\_\_\_\_\_\_\_ \text{ mL}}{\_\_\_\_\_\_\_\_ \text{ mL}}$$

DISTRIBUTION UNIFORMITY (DU) = ________

Calculate Precipitation Rate (PR) (using in)

$$\text{PR} = \frac{\text{Average Catch Can Depth}}{\text{Testing Run Time}}$$

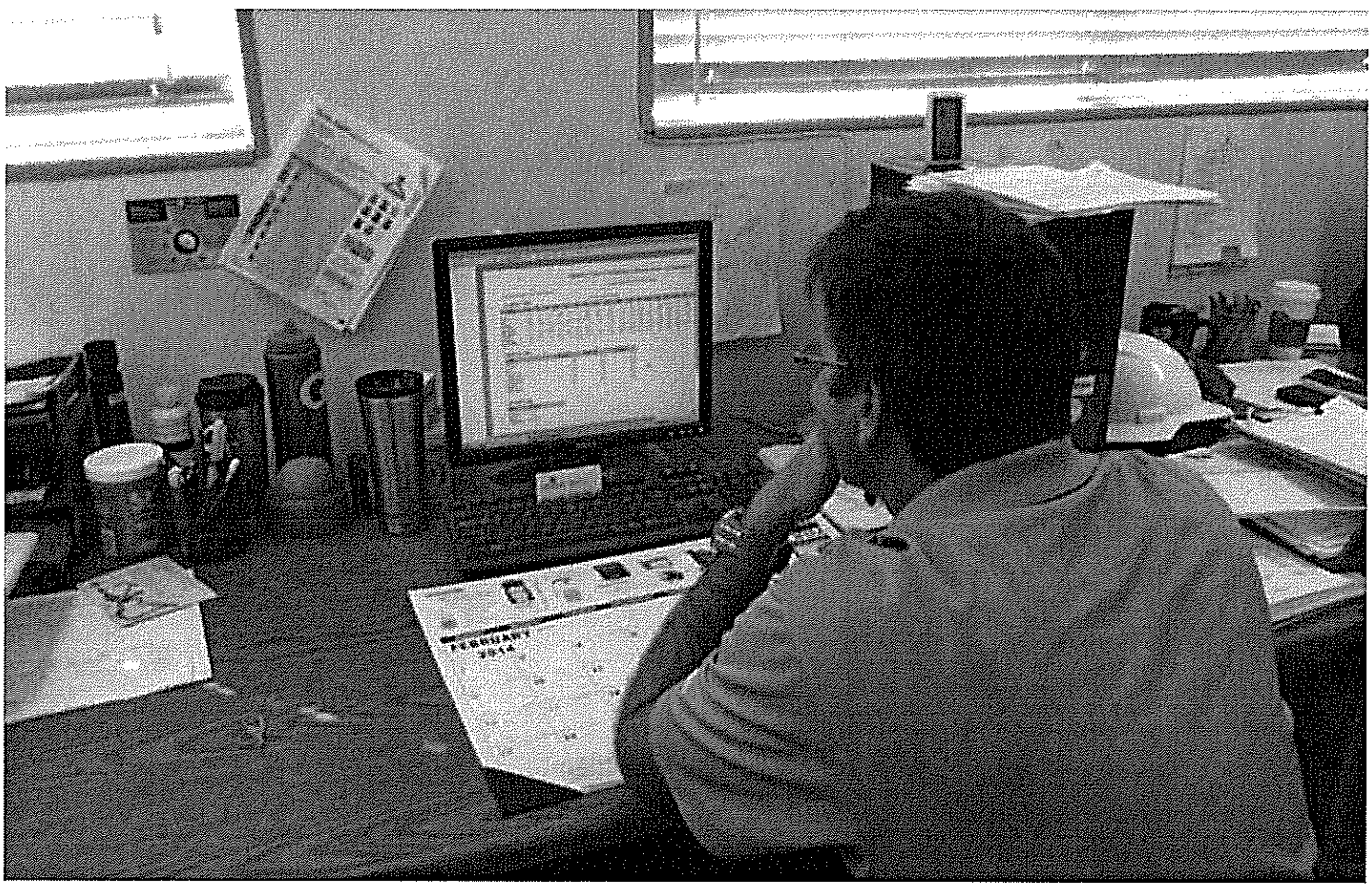
$$\text{PR} = \left[\frac{(\_\_\_\_\_\_ \text{ inches})}{(\_\_\_\_\_\_ \text{ minutes})} \right] \times 60$$

PRECIPITATION RATE = ________ in/hr

Developing a Preventive Maintenance Checklist for Golf Course Irrigation Systems

Proper maintenance can reduce labor and materials costs and may also help save water and energy while improving playing conditions.

BY BRIAN VINCHESI



A daily check of the central controller shows if the previous night's program operated on schedule. Adjustments to irrigation run times also can be made before the next irrigation cycle.

Irrigation systems are an integral part of golf course maintenance, just like maintenance staff, mowing equipment, and maintenance facilities. Without a functional irrigation system, it is virtually impossible to maintain golf course turf in playable condition. However, while mowers and other equipment are regularly seen working on a golf course, irrigation systems are a mystery to many golfers because they are buried underground and most frequently operate at night. Therefore, it can be difficult for golfers to understand that irrigation systems wear out and are very expensive to replace. A new irrigation system can cost $1.5 million or more, depending on location and complexity. Not surprisingly, most golf courses try to avoid this expense for as long as possible, especially since the true value of an irrigation system often is not fully understood.

Golf course irrigation systems can quickly deteriorate from lack of maintenance. Irrigation system maintenance is primarily reactive at most golf courses — i.e., when a component of the irrigation system breaks or is not properly working, an irrigation technician or assistant superintendent is dispatched to make repairs. Pre-

Sprinklers should be checked every week to ensure that they properly pop up, turn, and retract. Check that they rotate at the correct speed and that they are not leaking.

Sprinkler nozzles should be checked frequently for clogs and wear. Also, ensure that the proper nozzles are installed in each sprinkler.

Turf can grow over sprinklers and disrupt irrigation coverage, especially in rough and naturalized areas. Check and trim turf around sprinklers every month.

ventive maintenance can reduce the amount of reactive maintenance and improve playing conditions. Developing a preventive maintenance program is the best way to extend the life of an irrigation system, maintain performance, and minimize the severity and frequency of problems.

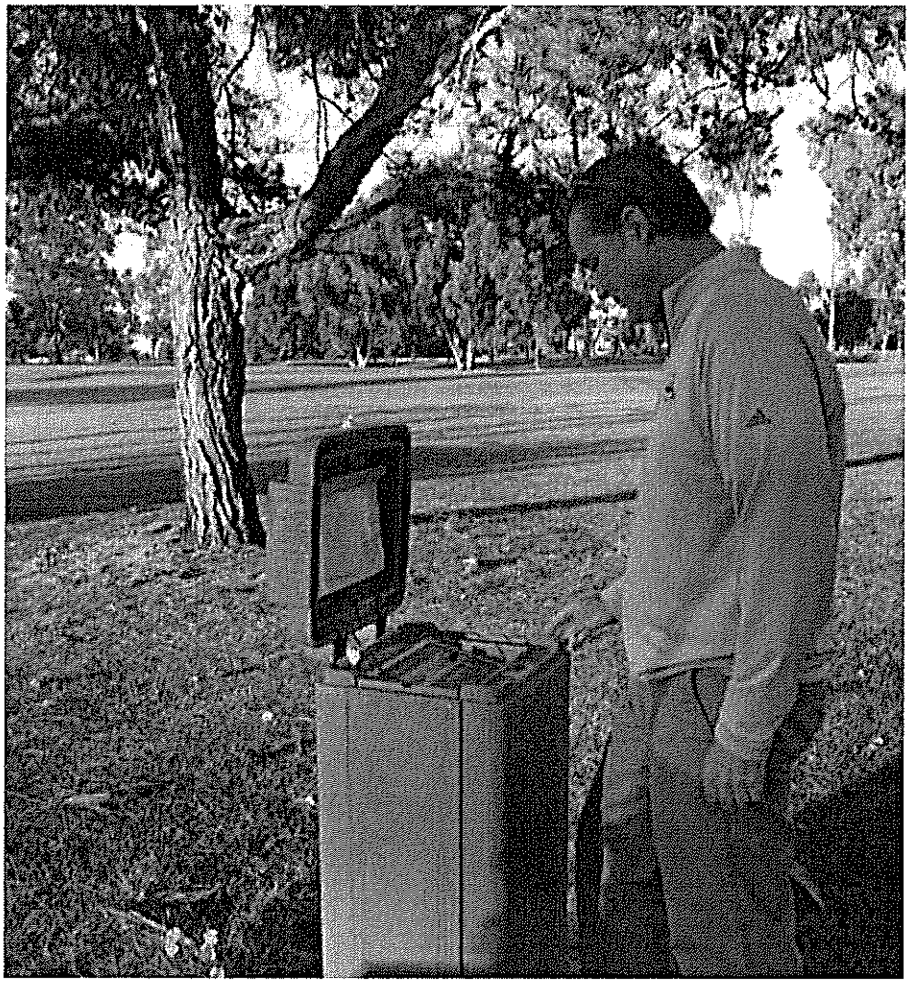
Preventive maintenance programs must be customized to meet the unique needs of an irrigation system, and they should be based on a thorough check of the system and its components. As with any preventive maintenance regime, some tasks will need to be accomplished on a daily, weekly, or monthly basis, while others may require attention quarterly, semi-annually, or annually. Of course, while preventive maintenance reduces irrigation system problems, it does not eliminate some tasks that must be completed on an as-needed basis.

So, what does a preventive maintenance program look like for the irrigation system at your golf course? It depends on the type of irrigation equipment and its age, but a typical program includes the observation, adjustment, and maintenance at regular intervals of sprinklers, valves, controllers, pump systems, and other components. The following sections of this article can be used to create a customized preventive maintenance checklist for any irrigation system.

DAILY MAINTENANCE

On a daily basis, the maintenance staff should perform the tasks that are a normal part of routine irrigation system operation and management. Examples include the following tasks:

- Observe golf course turf conditions for wet and dry spots.
- Review the irrigation program from the previous night to confirm that the irrigation system operated on the programmed schedule.
- Check the pump system monitor for any inconsistencies or abnormalities. This may be done remotely depending on your pump system equipment.
- Review and record water use from the previous night's irrigation cycle.
- Document evapotranspiration with a weather station or online source.

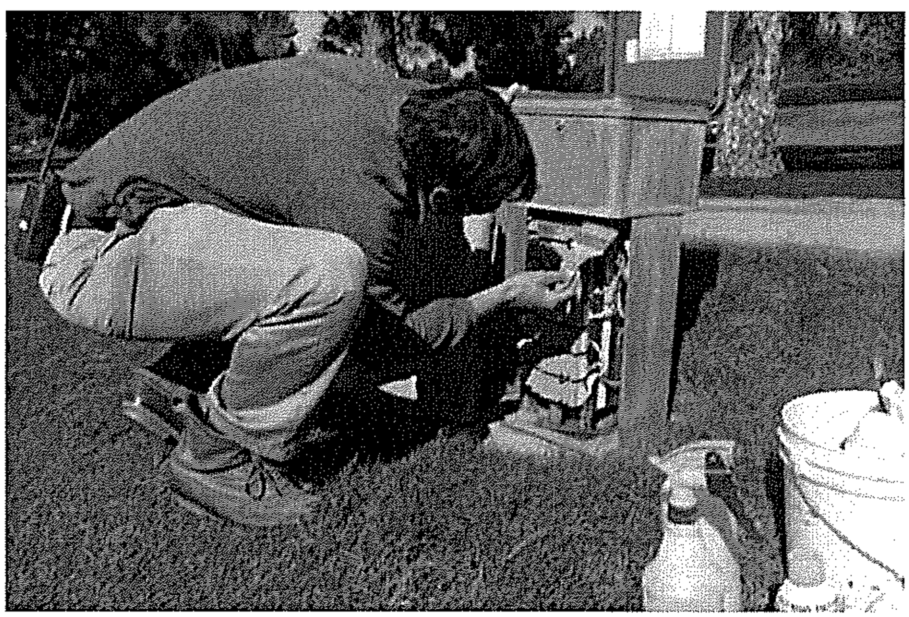


Checking the satellite controllers and central computer for backup programs and accurate run times should be done at least once every month.

system operation. On a weekly basis, time should be allocated to inspect the irrigation equipment itself and to make sure it is functioning correctly. Because the irrigation system most frequently operates at night, issues are not always obvious without inspection. Therefore, preventive maintenance on a weekly basis should include:

Check sprinkler operation to answer the following questions:

- Do any sprinklers appear to be turning faster or slower than usual? If so, time them to be sure.
- Does each sprinkler pop up, turn, and retract?
- Are part-circle sprinklers turning in the correct arc?
- Is there any leakage?
- Are any nozzles clogged?
- Update the central controller database with any changes.
- Check the condition of valve boxes and covers.
- Review the status of irrigation repair orders. Order necessary parts to complete repairs if they are not in stock.
- For two-wire systems, use software diagnostics to check the performance of each wire path for abnormalities such as excessive or unusual current draw and low-voltage reports.
- Visually inspect the condition of the pump station.
- Measure any precipitation using a simple rain gauge.
- Log any pipe breaks and component failures.
- For two-wire systems, check the operating log in the central control software diagnostics to verify normal communication between the central control software and each sprinkler or valve. Investigate stations that report possible issues.
- Prepare and prioritize irrigation repair orders and discuss them with the appropriate personnel. Assign additional staff to assist with repairs if necessary.
- Determine the water requirements for the next irrigation cycle and adjust the program accordingly.



Clean field satellite controllers quarterly by dusting, removing cobwebs, and replacing insect repellent. This can greatly extend the life span of electrical components.

WEEKLY MAINTENANCE

Daily observation and maintenance should occur as part of normal irrigation

MONTHLY MAINTENANCE

Approximately once a month, the staff should:

- Check that sprinklers are not blocked by surrounding turf and trim around sprinklers as necessary.
- Inspect valve assemblies for leaks or damage.
- Examine and clean filtration devices. Check for wear on filter screens.
- Review and consider adjusting temporary changes made to irrigation station run times during the previous month.
- For two-wire systems, use software diagnostics to run a voltage check of every sprinkler or valve in the field. Compare voltage readings to results from the previous month to verify that there is no unexpected drop in voltage.
- Inventory and restock irrigation repair parts.

QUARTERLY MAINTENANCE

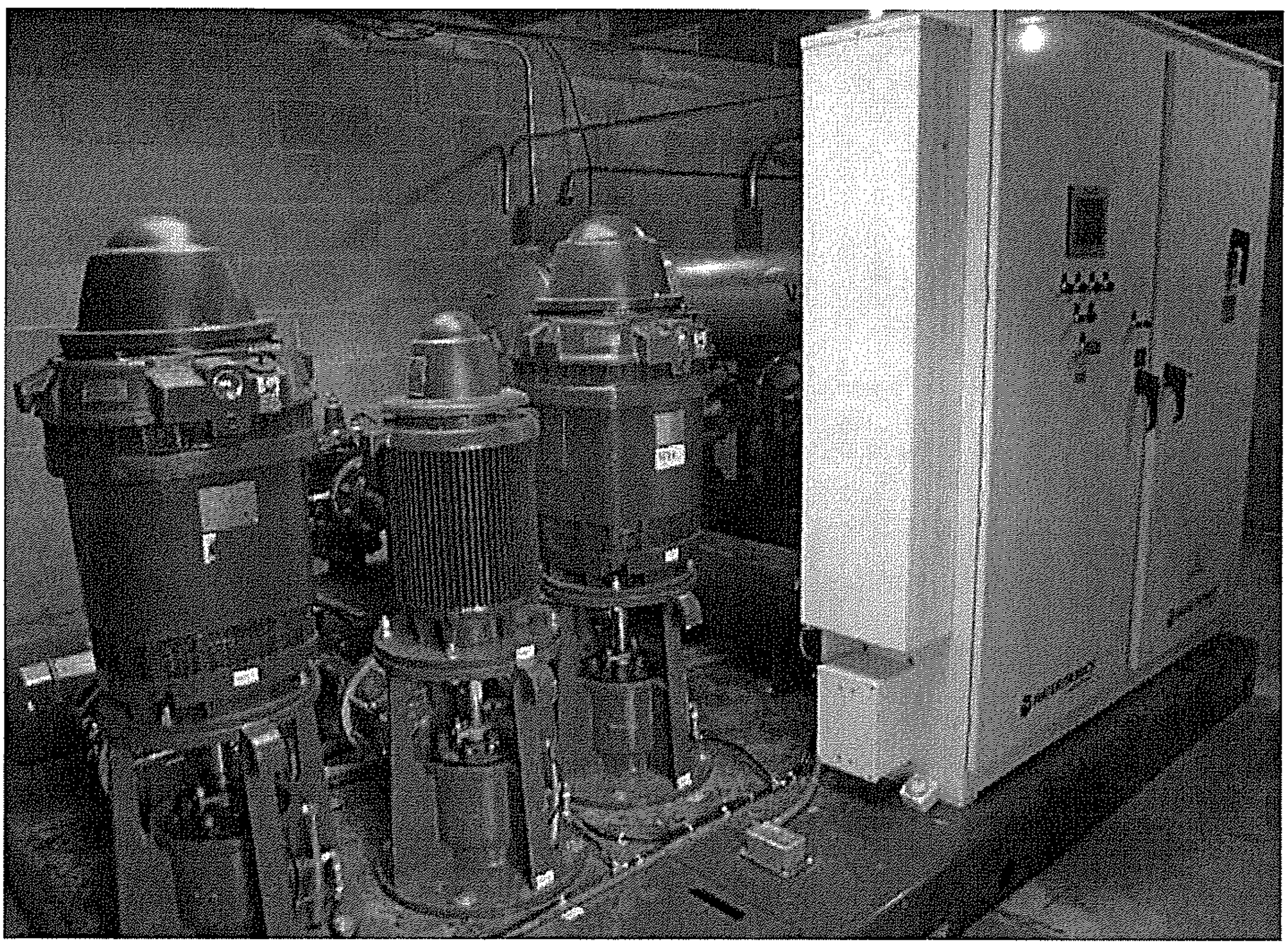
Dust, dirt, and debris can damage irrigation controllers and pump systems. Quarterly cleaning can significantly extend the life of system components, especially electrical items such as central computer controls and field satellites. Quarterly maintenance should include:

- Clean satellite controllers and replace insect repellent.
- Clean the pump system, pump house, and irrigation parts room.
- Remove dust from the central computer using a compressed-air duster.
- Check if software updates are available for the central control system and install them as necessary.
- Clean out rain gauges.
- Listen to the pump system as it starts up and shuts down during an irrigation cycle to ensure that it is operating correctly. Check to ensure that pumps turn on and off smoothly, watch for excessive cycling, and listen to how the drive ramps up and down.

SEMIANNUAL MAINTENANCE

Exercise all quick couplers on the course, especially those that are rarely used.

- At minimum, record pressure readings at high and low points of the irrigation system using quick couplers and a pressure gauge. Compare readings to previous results and note any changes in pressure to identify potential problems.
- Pump system service should occur semiannually at minimum in climates with a 12-month irrigation season.



Pumps are the heart of an irrigation system. Semiannual maintenance of electrical and mechanical components by a trained technician ensures efficient operation.

ANNUAL MAINTENANCE

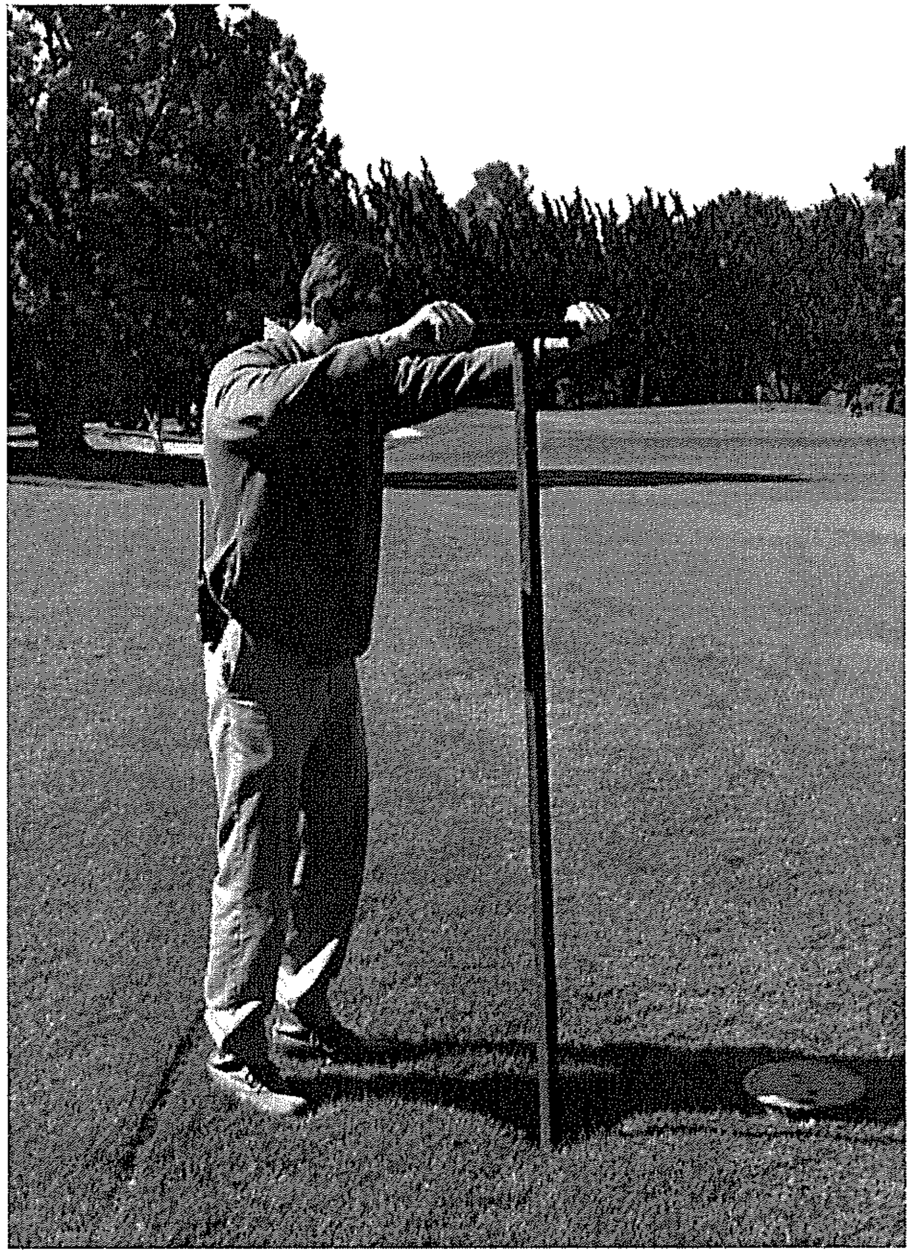
Exercise all isolation valves and drain valves to prevent them from sticking open or closed.

- Pump system service should occur annually in climates with a six- to eight-month irrigation season.
- Pressure-wash pump system filter or "Y" strainer screens. Check intake screens for clogging and debris.
- Test and certify the function of any backflow prevention devices. Hire a certified technician who works in accordance with state and local testing requirements.
- Test and service pressure-regulating devices.
- Test, clean, and service air-release valves by flushing "Y" strainers and exercising ball valves.
- Drain and winterize piping systems in cold climates.
- Level and set sprinklers and valve boxes to grade.
- Check antennas and their connections.
- Back up map and program databases on the central control system to an external device.
- Renew central computer service plan and update the computer according to service schedules.
- Check field controllers to ensure that backup programs are still installed and relevant.
- Calibrate flow meters on the pump system and water sources.
- Run a test of the battery backup that protects the central computer and replace it if necessary.
- Verify that a sample of grounding readings continues to meet manufacturer specifications. Compare readings across years to identify changes that could indicate reduced lightning protection.
- Check the calibration of weather station sensors and check all connections.
- Inspect quick-coupler hoses and hose-end fittings.

AS NEEDED

If necessary, hire a contractor to inspect the pump intake and clear any accumulated debris.

- Repair or replace pump intake screens.



Isolation valves and drain valves should be exercised annually to prevent them from sticking open or closed.

- Rewind pump motors and rebuild turbine pumps, replacing seals, bowls, and bearings.
- Perform an irrigation field audit every three to five years to monitor water distribution uniformity and sprinkler performance.

DIAGNOSTICS AND REPAIRS

With new technology, some of these tasks can be automated or are incorporated into the features of irrigation equipment. Today's central control systems have the ability to diagnose or troubleshoot many aspects of a golf course irrigation system. They are often able to pinpoint where problems are occurring and can provide diagnostic data such as voltages and amp draws at every sprinkler. These troubleshooting features, currently available with newer irrigation systems, will only expand and improve in the future.

In order to efficiently service an irrigation system, it is important to maintain a small, on-site inventory of irrigation parts. It is difficult to perform maintenance when parts must be ordered every time something goes wrong. Parts inventories should be diverse. However, every golf course should have at minimum a selection of fittings, a small amount of pipe, and repair couplings for every size of pipe used in the irrigation system. Additionally, sprinkler bodies and internals, sprinkler control wire, wire connectors, gate valves, and a variety of nozzles should be readily available. Other items that are good to have on hand include a spare faceplate and several spare circuit boards for field controllers; an electrical multimeter for testing voltage, amperage, and resistance; a metal detector; and a wire locator. Two-wire systems will require more specialized diagnostic equipment such as a clamp meter and wire radar device.

A selection of pipe fittings and repair couplings of different sizes should be on hand so that repairs can be made in a timely manner.

Depending on the age and amount of time required to maintain an existing irrigation system, employing an irrigation technician may be advantageous. Irrigation technicians focus on performing both reactive and preventive maintenance, checking pump system operation, and keeping the irrigation computer database accurate. If you have a large irrigation system — e.g., an irrigation system with 2,500 sprinklers or more — you may need two or more irrigation technicians. A properly trained irrigation technician will keep an irrigation system functioning as intended while reducing additional costs. A side benefit of proper irrigation system maintenance is the potential for reduced water use. When an irrigation system is in good condition, it is more efficient and saves both water and energy.

CONCLUSION

Although a preventive maintenance program will not make an irrigation system last forever, it will reduce the labor and materials costs associated with keeping the system operational. It may also help save water and energy while improving playing conditions. A well-maintained irrigation system can even help reduce the stress level of maintenance staff by providing a dependable system they can rely on during hot, dry days when it is most needed.

BRIAN VINCHESI *is president of Irrigation Consulting, Inc., a golf course irrigation and consulting firm headquartered in Pepperell, Massachusetts, that designs irrigation systems throughout the world. He can be reached at* bvinchesi@irrigationconsulting.com.

USGA.

Identifying Fittings and Parts and Making a Parts Run

How many of you have been stuck in a muddy hole trying to put things together when you realize the part doesn't fit, won't work, or is just plainly the wrong kind of part? I've been there, and it's incredibly frustrating!

Or you are at the parts store and they don't have the piece you need, and you don't have time to order one and need to get the job done now! So, you try to find a way to piece different parts together to get the project done.

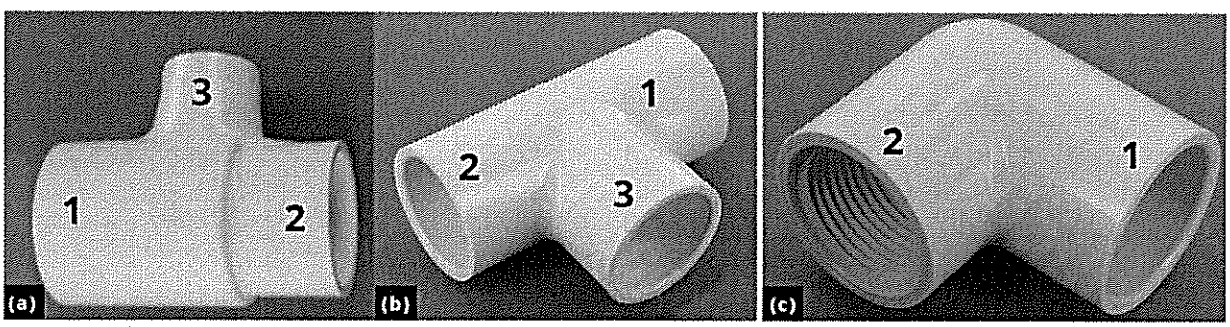
Our first objective is to learn how to identify the parts you have on hand and are working with and understand how they fit together.

For your review, here is a list of common terms and abbreviations.

- **S or Slip**: A regular hub. The pipe glues into this (same O.D. as coupling)
- **MIPS**: Male pipe threads on the outside of the fitting
- **FIPS**: Female pipe threads on the inside of the fitting
- **Mipt**: Male pipe threads on the outside of the fitting (same as MIPS)
- **Fipt**: Female pipe threads on the inside of the fitting (same as FIPS)
- **Spigot or SP**: The same size as the pipe. Will glue into another fitting
- **MHT**: Male hose threads (garden hose)
- **FHT**: Female hose threads (garden hose)
- **Barb**: Barbed fitting
- **Saddle**: Attaches to the side of the pipe

When identifying a fitting such as a 'TEE,' there is a specific sequence to identifying all of the connecting locations and their connection type.

In the figures below (1a-1c), you can see a counter-clockwise pattern of identifying fitting joints and sizes.

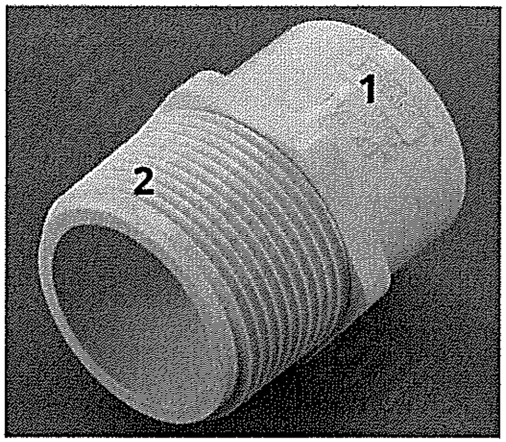


Credit: "1" PVC Fittings" by plumbingsupply.com and are used under Fair Use.

How to characterize the fittings:

- Figure (1a) is a: *(1)* 1-inch x *(2)* ¾-inch x *(3)* ½-inch reducer TEE. *(1)* Slip x *(2)* Slip x *(3)* Slip (SxSxS).
- Figure (1b) is a: *(1)* 1-inch x *(2)* 1-inch x *(3)* 1-inch Service TEE. *(1)* Slip x *(2)* Slip x *(3)* FIPT (SxSxFIPT) (it may also be called just a 1-inch service TEE, or referred to as a combo TEE)
- Figure (1c) is a: *(1)* 1-inch by *(2)* 1-inch Service EL. *(1)* Slip by *(2)* (or combo EL)

When working with fittings like Figure 2, it is often recommended to start with the Slip/Socket end.



Credit: "Slip/Socket End" by plumbingsupply.com and is used under Fair Use.

Figure 2: 1-inch male adapter MA, Slip by MIPT.

If it was adapting from 1-inch slip to ¾-inch male threads, it would be referred to as a reducing male adapter.

It is important to understand the general concepts of identifying fittings (fitting nomenclature) because each manufacturer may list their parts with slight variations that can make it difficult when looking for your parts online or speaking with an industry representative.

During the installation process of an irrigation system, you may be given the design installation specifications of a particular head from the consulting architect (Figure 20). If you are charged with installing this part of the system, it will be important to do it as per plan to honor the warranty in case of future failures and potential replacements.

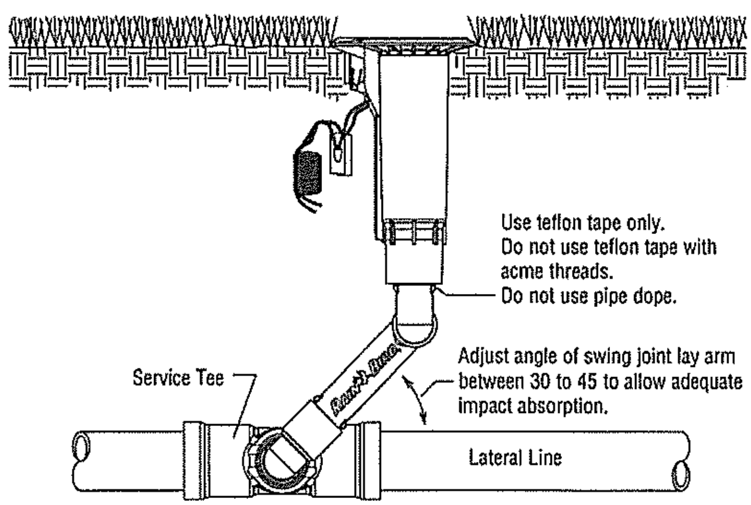
Example:

In **Figure 3**, you are using premanufactured swings joints and are told the correct angle, and to use Teflon tape if threaded.

Question: Let's say you are indeed using threaded swing joints and you ran out of Service Tees.

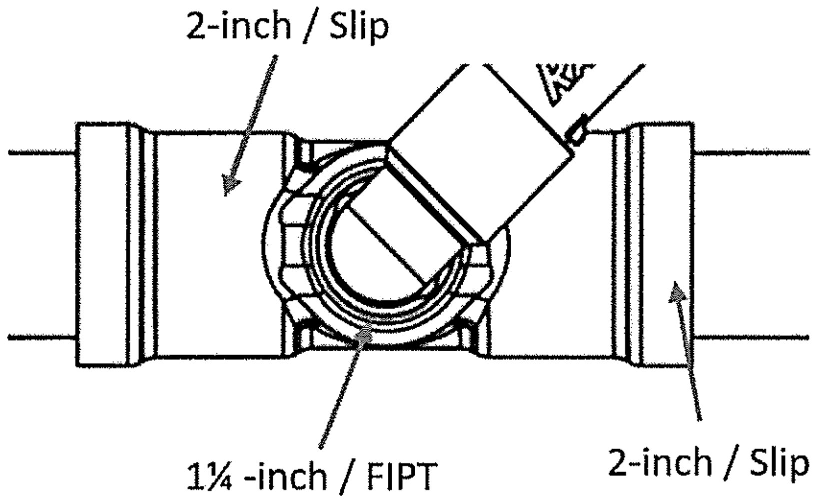
You need to order a case of them, what do you order (the lateral pipe is 2-inch and the swing joint is 1¼ - inch)?

Figure 3: Specification installation plan for a Rain Bird® golf rotor.



Credit: "Rain Bird Golf Rotor" by Rain Bird and is used under Fair Use.

The next illustration would be a relatively simple example of how to figure out what part you need to order. This will save you a lot of time from having to hunt through an online store or trying to explain what you need to service-counter personnel.



Credit: "Service Tee Fitting" by Rain Bird and is used under Fair Use.

Figure 4: Close up of service tee fitting.

Answer: 2" x 2" x 1 ¼ " Service Tee. SxSxFIPT (Figure 4).

The previous illustration would be a relatively simple example of how to figure out what part you need to order. This will save you a lot of time from having to hunt through an online store or trying to explain what you need to service-counter personnel.

https://www.lascofittings.com/fluiddynamics

LASCO _ Information on Fluid Dynamics and Water Hammer

Pressure Surges on PVC Pipes

Everyone is familiar with the phenomena of "Rattling Pipes" when turning on and off water systems within the house. Pressure surges in piping systems are very common and many times can be destructive too. The typical cause of this rattling is that of "Water Hammer" and is caused by valve operation, entrapped air in the line and some pump operations. The effect of any one of these above events can be effectively multiplied many times by the geometry of a piping system. If the pressure wave is allowed to reflect (bounce) back and forth within the system.

"Valve in head" sprinklers used by turf irrigation systems are very good examples of a component which can cause water hammer. The combination of the high flow velocity within the valve and the instantaneous on-off, set the stage for large surges within a system. Add to this the fact that a turf irrigation system which would use these types of valves is operated daily and in some cases more than once a day. Therefore, the frequency is increased and adds to the problem.

Because the industry standards relating to pressure ratings of PVC fittings and pipe are all based on static pressures and no mention is made of surge conditions which are known to take place within installed systems. It is often found that no allowance has been made for the surge pressures by the system designer. This condition leads to a working condition that allows surges to exceed the static pressure rating of pipe and fittings, thereby causing damage.

Some of the approaches to eliminating this problem have been suggested by such people as the Farmers Home Administration which puts an extra safety factor in the rating of thermoplastic pipe by recommending that the operational pressure not exceed two-thirds (2/3) of the maximum rated pressure by ASTM. The Soil Conservation Services Engineering Standard 430-DD recommends the working pressure be held to a maximum of 72% of the ASTM ratings and limits flow velocities to 5 feet per second. These measures increase the margin of safety but cannot guarantee that surges won't be generated and damage result.

The ASTM pressure ratings were never meant to be a fool proof system whereby all other cautions can be ignored. It is a known fact that frequent pressure surges or fluctuations in a piping system will cause a fatigue failure. By the proper placement of gauges, recorders and early design consideration, these conditions can be held to a minimum to prevent future failures.

When surges continue and a fatigue failure occurs, there are certain characteristic features that can be seen in the failure. A short split will be observed in the wall of the pipe or fitting. The area adjacent to that split will erode away be the "Slurry" of water and soil that is churned up during the normal operation of the system. Occasionally the split and the erosion will continue to lengthen into a larger pit or adjacent pockets on the wall. With extremely high surge pressures that are typical of water hammer failures, the pipe and/or fitting will shatter and the fracture pattern points towards the origin of the failure. If the pipe is colored, a V-shaped, whitened area will be visible at the ends of the original split.

Various factors influence the life of a system operating under cyclic conditions, such as:

• maximum pressure

• difference between maximum/minimum pressure

• operating temperature

• chemicals within the system frequency and duration of surges

The maximum stress observed within a pipe wall during a surge is the largest single factor influencing the time to failure of a system. If the surge is large enough, failure will occur in one cycle (i.e., Quick Burst). With other factors held constant, it is possible to determine a stress vs. cycle failure relationship. However, these studies can only be guidelines for actual (real world) performance and design cannot exactly predict the cyclic life in real application. For instance, the range between maximum/minimum pressure is very important and as the two pressures approach each other the surge effect disappears and the pipe experiences essentially a static pressure. The most damaging situation is with wide fluctuations and pressures. Surge life is also affected by the operating temperature of PVC. PVC being a thermoplastic means it is softer when it is heated and when operating above 73 degrees Fahrenheit, both the static and surge life is reduced as well as the stiffness. This is normally not a consideration in municipal and turf water systems. However, it may become important in warm climate irrigation or surface irrigation where the water is heated due to the elevated temperature. Insufficient data is available to establish if these static pressure factors are appropriate corrections for water hammer conditions.

The effect of a pressure wave form is probably the least investigated and least understood variable in the investigation of cyclic behavior. The wave form describes how rapidly the pressure rises and falls and how long it remains at the higher or lower level. Various pressure forms such as a saw-tooth (steady rise/sharp drop), spike (rapid rise immediate fall), square (rapid rise hold at the high pressure, rapid fall), and many combinations have been observed. When the pressure peaks and falls rapidly, the PVC may not fully respond to the applied load. Rising slowly allows time for material to reorient or adjust to the load level. Cycle rate also has a direct effect on using up the life of a system. If a system will tolerate a million surges for a chosen design pressure, an increase in the surges from 1 hour to 10 hours will produce a failure rate in

1/10 of the time. This proportional relationship will be maintained in all systems.

Keeping in mind factors that produce surge, such as high flow rate and rapid valve closure, it is apparent that many problems can be solved in the system design stage. There is no single solution applicable to every situation. Consideration must be given to the design of the pump, the operation of the valves and regulators. This may involve choosing an alternate type of pump, control system, and/or surge tank. Valve controls should be designed for slow opening and closing and piping should be.

The maximum possible surge should be estimated along with the anticipated surge frequency. PVC pipe can tolerate occasional surges well above the design rating of the pipe. However, when repetitive surges are expected, they should be controlled below the pipe design rating. As stated earlier, FHA and the Soil Conservation Services recommendation of 67% and 72% of the static pressure design are useful guidelines for ASTM design pipe.

The obvious question is how many surges can a system tolerate. An exact answer is not possible, because we can make only an estimate. Tests have shown that peak pressures (saw-tooth wave form) that cause stresses in the range of 2500 psi will cause fatigue at about 140,000 surges. At a peak stress of 1500 psi, fatigue occurs at 2,220,000 surges. Some variation will exist in each application because the base pressure and pressure wave form will be different in each test condition.

What does 2,000,000 surges represent? In a controlled system with 10 cycles per day, 548 years of service. However, in a less controlled system with 10 cycles per hour, the result is 23 years of service. As a rule, municipal water systems are reasonably controlled and long service life is expected. Some difficulties have been observed in uncontrolled golf course installation where surges exceed the static pressure rating of the pipe and occurred hundreds of times daily. In this situation, the service life of the golf course was reduced to a range of two to five years.

Pressure surges damage all components of a piping system: pumps, valves, fittings, and pipe. If the system is to operate satisfactorily for many years, water hammer must be controlled. Control begins with good design and continues to good operation. Proper equipment selection, including the use of pipe and fittings with appropriate pressure rating, is the good starting point for a successful installation.

PVC Pipe and Water Hammer

The elastic or non-rigid nature of PVC greatly reduces the pressure wave or surge pressure that travels through the piping system. PVC's ability to swell or grow slightly helps to dissipate some of the energy created as the pressure wave travels through the system.

However, PVC is also visco-elastic. This means that it can't tolerate sudden changes or forces. Because of this, water hammer may be a problem in PVC systems. Water hammer is the impact force caused by the sudden adjustment in pressure due to changes in the velocity of water traveling through a pipe. Fortunately, there are some steps which can eliminate any system failure due to water hammer.

Quick-closing valves

The maximum surge pressure generated in a 2-inch Schedule 40 PVC system flowing at 5 feet per second is about a third as great as the surge pressure generated in a steel or copper system. Wave velocity is also very slow - about the same 3:1 ratio. This can produce water hammer in a system with quick-closing valves. Therefore, the valve closing times in a PVC system must be much longer than those in a metal system in order to prevent water hammer.

Air Slugs

Another common cause of water hammer is an air slug. An air slug is nothing more than a bubble or air pocket within the system. They usually rest at the highest point in a pipe. When this bubble travels through the piping at the velocity of water, there is no real problem. The problem occurs when the air slug gets to the sprinkler. The air escapes through a sprinkler nozzle approximately five times faster than water, so the upstream water velocity suddenly increases. When the air slug is gone, the system velocity suddenly drops to the original value. This can shock the system causing damage.

For example, if the normal velocity is 3 feet per second, the system can increase to 15 feet per second during air escape, and it can be instantly reduced by 12 feet per second to the original speed. That 12 feet per second change will create an additional pressure of more than 200 psi in that 2 inch system. This 200 psi surge, added to the working pressure of 100 psi, exceeds the 280 psi rating of Schedule 40 pipe.

The 200 psi surge will only last about a third of a second. However, with a surge that size, even for that brief time, broken piping and components may be the result.

To reduce damage due to air slugs several things can be done. First, you must properly fill the system with water from the start. When filling for the first time you open the valve to about 1/4 open. Filling the system very slowly works the air slugs out. If air slugs are still a problem in the system you can install air bleed release valves at high places in the pipe where air slugs collect. These release valves open to release the air when the system is turned off but close when water is running through the pipes.

While PVC can greatly reduce pressure waves or surge pressures due to its elastic nature, it is visco-elastic and cannot tolerate sudden changes or forces. However, water hammer does not have to be a problem. Designing the system with water hammer in mind can solve the problem.

Friction Loss of PVC Pipe

One of the major advantages of plastic pipe is its smooth inside surface, which minimizes the amount of friction loss compared to other materials. Essentially this means that in plastic systems there is a possibility of using smaller diameter pipe while obtaining the same or lower friction losses than with other materials.

LASCO Fittings Inc. has taken every reasonable effort to provide reliable information in this report to give engineers, users, contractors, code officials, and other interested parties essential information on the water flow characteristics of thermoplastic pipe.

The following charts show the friction-loss characteristics of various schedules class' and sizes of plastic pipe.

No warranty or guarantee can be assumed for piping installations. The data shown has been compiled from various sources. It is not all-inclusive and is intended for use as a general guide.

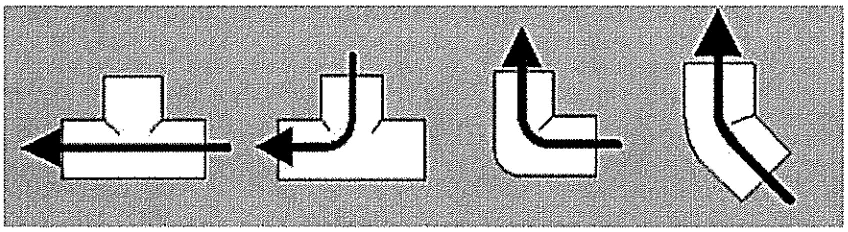
The "C" factor in the Williams and Hazen formula is 150 for plastics and less for metallic pipe.

It is important to note that the PVC pipe and fitting manufactures recommend that design velocities do not exceed 5 feet per second. Excessive velocities can lead to failures from surges and water hammer.

Friction Loss of Fittings

The amount of friction loss of fittings is important when designing PVC systems. The following table is provided by LASCO Fittings, Inc. to provide information regarding friction loss of fittings in equivalent feet of pipe.

Friction loss of fittings shown in equivalent feet of pipe



Size	tee-run	tee-branch	90° ell	45° ell
1/2	1.0	4.0	1.5	0.8
3/4	1.4	5.0	2.0	1.0
1	1.7	6.0	2.3	1.4
1¼	2.3	7.0	4.0	1.8
1½	2.7	8.0	4.0	2.0
2	4.3	12.0	6.0	2.5
2½	5.1	15.0	8.0	3.0
3	6.3	16.0	8.0	4.0
3½	7.3	19.0	10.0	4.5
4	8.3	22.0	12.0	5.0

This chart is based on a Hazen and Williams coefficient of 150.

For example: a ½-inch tee-branch fitting has the friction loss equal to 4 feet of pipe. Therefore, 100 feet of 1/2 inch pipe containing one Tee-Branch fitting has the same friction loss of 104 feet of straight pipe.

Variations may result from installation techniques, actual fitting geometry, and inside diameter of adjacent piping system. Due to these variations, this information should only be used as a reference point.

Water Hammer and Surge Pressures

Hydraulic Shock Valve Closing Pressure surges are produced by unsteady flow resulting from either acceleration or deceleration of a liquid. Every flowing fluid accumulates kinetic energy (velocity head), the strength of which is determined by the weight of the fluid and the speed with which it is moving. If the speed of this fluid is changed, i.e., suddenly slowed or stopped, the kinetic energy is transformed into pressure energy and causes the normal system pressure to increase. This phenomenon is called hydraulic shock or, more often, "water hammer". If left uncontrolled, it can produce forces large enough to damage a piping system permanently.

When a fluid is flowing with a constant velocity through a pipe and a downstream valve is closed, the following sequence of events takes place:

1. The water adjacent to the valve is stopped
2. The momentum in the fluid is converted to a pressure head
3. The fluid compresses and expands the pipe walls
4. The flow of adjacent particles within the water is successively brought to rest
5. Momentum is transformed into pressure energy.

When the water is compressed due to the sudden stop., the pressure wave travels upstream to the end of the pipe at wave velocity - "A". If the pipe length is "L", then after L÷A seconds the wave will be at the upstream end. The pressure wave, after reaching the upstream end (i.e. valve, etc.) of the pipe, is reversed and returns to the downstream valve at 2L÷A seconds after valve closure. During this time, the fluid pressure and the pipe stress will be greater than normal. If the fluid were ideal, there would be no resistance to flow and surges would continue to repeat indefinitely. With friction and pipe elasticity, the pressure amplitudes diminish gradually until original momentum is absorbed. The explanation of water hammer in the previous paragraphs assumes instantaneous closure. But valves require a finite time to close. If closure takes place in a time less than 2L÷A, then it is termed "critical" (TC) and the incremental pressure rise is shown in the **Table 1**.

V = VELOCITY CHANGE, (Feet/Second)	= 1
L = PIPE RUN LENGTH, Ft.	= 100
W = FLUID DENSITY, #/Ft.3	= 62.4 (WATER)
K = MODULUS OF FLUID, PSI.	= 300,000 (WATER)
E = MODULUS OF MAT'L. PSI.	= 400,000 (PVC)
DR = DIMENSION RATIO (IN./IN.)	= PIPE O.D.÷ WALL THICKNESS
A = WAVE VELOCITY (Feet/Second)	= 4,660÷[1+{K x (-2+DR)÷E}]1/2
TC = CRITICAL VALVE CLOSE TIME (Sec.)	= (2 x L)÷A
P = PRESSURE CHANGE (PSI) (PEAK)	= (W x A x V)÷4,636.6, (ADDS TO FLOW PRESS.)

Table 1 shows the increase in water pressure of a system for each one foot per second flow rate and each 100 feet of PVC pipe. For other "Run" lengths and "Velocities" multiply "Peak Pressure Surge" accordingly.

Table 1

Dimension	(DR) Ratio	Rated Pressure	(A) Wave Velocity	(Tc) Critical Close Time	(P) Peak Surge Pressure
All Sizes	13.5	315	1,502	0.13	20.21
All Sizes	17	250	1,331	0.15	17.92
All Sizes	21	200	1,193	0.17	16.06
All Sizes	26	160	1,069	0.19	14.39
All Sizes	32.5	125	954	0.21	12.84
SCHEDULE 40 PIPE					
1/2	7.7	600	2,029	0.10	27.31
3/4	9.3	480	1,831	0.11	24.65
1	9.9	450	1,771	0.11	23.83
1¼	11.9	370	1,605	0.12	21.61
1½	13.1	330	1,526	0.13	20.54
2	15.4	280	1,402	0.14	19.69
2½	14.2	300	1,463	0.14	19.69
3	16.2	260	1,365	0.15	18.37
4	19.0	220	1,257	0.16	16.91
5	21.6	190	1,176	0.17	15.83
6	23.7	180	1,121	0.18	15.09
8	26.8	160	1,053	0.19	14.17
SCHEDULE 80 PIPE					
1/2	5.7	850	2,398	0.08	32.28
3/4	6.8	690	2,173	0.09	29.24

Dimension	(DR) Ratio	Rated Pressure	(A) Wave Velocity	(Tc) Critical Close Time	(P) Peak Surge Pressure
1	7.4	630	2,074	0.10	27.91
1¼	8.7	520	1,898	0.11	25.55
1½	9.5	470	1,810	0.11	24.37
2	10.9	400	1,682	0.12	22.64
2½	10.4	420	1,725	0.12	23.21
3	11.7	370	1,620	0.12	21.80
4	13.4	320	1,508	0.13	20.29
5	14.8	290	1,431	0.14	19.26
6	15.3	280	1,407	0.14	18.93
8	17.3	250	1,319	0.15	17.76

- Peak surge pressure (P) is directly proportional to the velocity changes (V). P tabled above is per foot/sec. Velocity change.
- Critical valve close time (TC) is directly proportional to the pipe run length (L). TC tabled above is per 100 ft. Of run length.
- If actual valve close time (TA) is less than the critical time (TC), then the peak surge is as shown, but if TA is greater than TC, then the approximate pressure surge is (PA) = (0.027 x L x V)÷TA (psi).
- Air slugs in a system can create surge velocities far in excess of the system design flow rate. Abrupt flow changes and high flow rates can compound to create very high hydraulic pressure shocks.

Pipe Fitting Connector Types

There are many different pipe fitting types. From spigots to barbed inserts to compression, the look and purpose of different PVC end types vary widely. This section will act as a guide to help newcomers to the world of PVC and may also serve as a refresher for our seasoned veterans.

Slip, Socket, and Spigot

Our first end type is the **slip** fitting. It may be termed as **slip** or **socket** or **spigot**. All of these terms refer to the fact that there are **no threads or barbs**. To secure a **slip** fitting, a solvent cement is used. Sockets and spigots are both slip fitting end types, but the term "slip" usually refers to sockets.

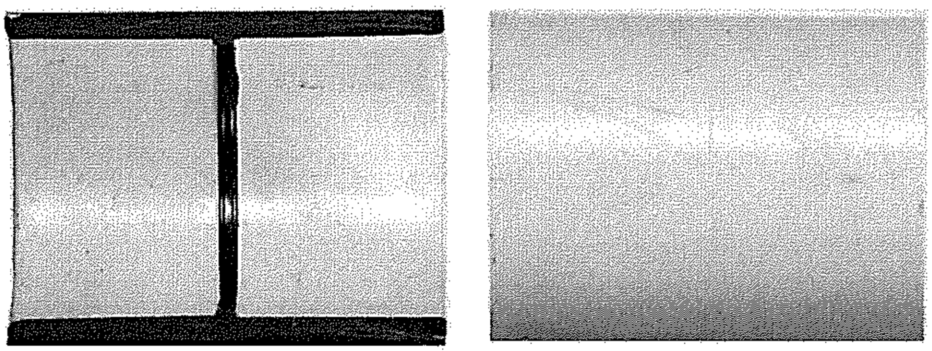


Figure 1: PVC slip coupling (inside cutaway and outside views).

- A **socket** is a fitting that simply goes over the end of a pipe (a 1" socket end will fit on a 1" pipe). In their function, sockets are considered a female end.
- A **spigot** fits inside a socket, so it is the same size around as regular pipe (when you need to attach a fitting to another fitting, you use a spigot end). In their function, spigots are condered a male end.

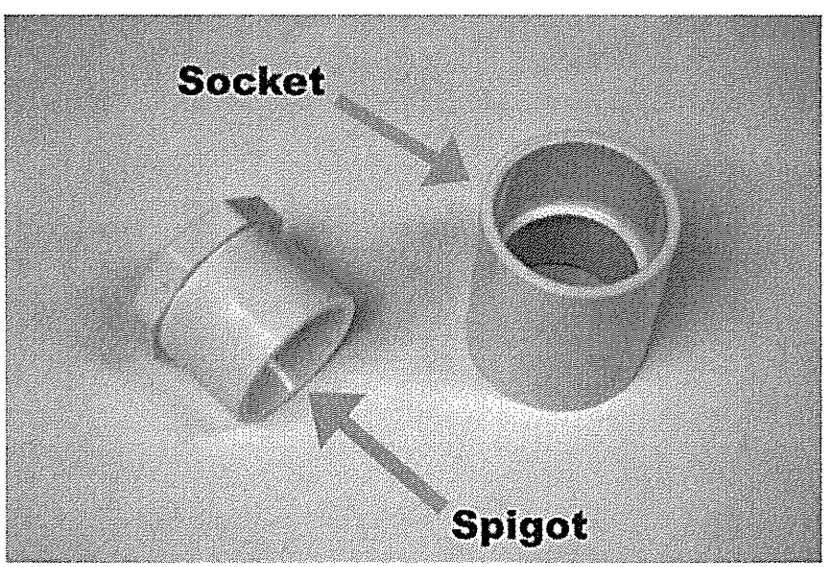


Figure 2: PVC socket and spigot fittings.

Spigot fittings are often called **street** fittings. The terms "street," "spg," and "spigot," are all the same thing and refer to spigot end fittings. The picture above shows a **1.5" coupling with socket ends** and a **1.5" × 1" bushing with a spigot end**.

Threaded

IPT (Iron Pipe Thread) or **NPT** (National Pipe Thread) has become a U.S. standard for tapered threads used on pipe and fittings. The taper rate for all NPT thread is 1.6 mm. You can see the taper in the fitting threads in Figure 7.3.3. When torque is applied to an IPT/NPT fitting compression will cause the flanks to create a seal; as opposed to the alternative parallel or straight thread fittings, which thread merely to hold pieces together not to provide a seal.

With threaded fittings, there are **female-threaded** (the threads are on the inside) and **male-threaded** (the threads are on the outside) fittings. Accordingly, a male-threaded fitting can be secured into a female-threaded fitting.

To secure a leak-free joint, Teflon tape is most commonly used. However, a non-hardening sealant for threaded joints is often recommended because of the internal stress added by the incorrect application of Teflon tape due to the tapering (and thinning) of the pipe wall for female threaded fittings.

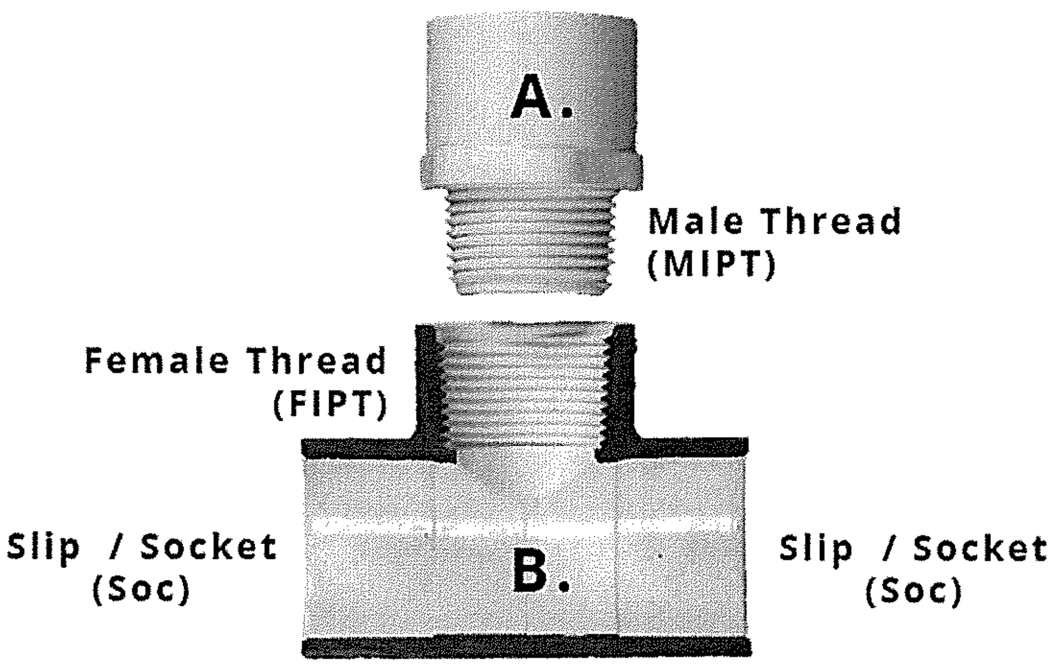


Figure 3: Male- and female-threaded joints (with slip/socket joints). (A) is a 1" male adapter — MIPT × Slip; (B) is a 1" combination tee — Slip × Slip × FIPT.

As shown in Figure 3, many threaded fittings have slip fittings on the other end to more easily connect to pipe. These are often referred to as **combination** or **service** fittings.

When browsing female-threaded fittings, you may see the abbreviations **FPT** and **FIPT**. These stand for **female pipe thread** and **female iron-pipe thread.** For male-threaded fittings, you will see the same abbreviations with an **M** instead of an **F** and stand for **male pipe thread** and **male iron-pipe thread.** If you recall, PVC pipe was originally based on galvanized iron pipe, hence the reference.

Barbed Insert or "Insert"

Connecting PE pipe employs fittings with **barbed insert** ends. The word **barbed** refers to the ridges on the fitting that are meant to keep the pipe from slipping off. To seal and secure a barbed insert fitting, you must use a clamp. When looking for barbed or insert fittings, you will often see **barbed insert** shortened to **Insert** or **Ins** or **I**.

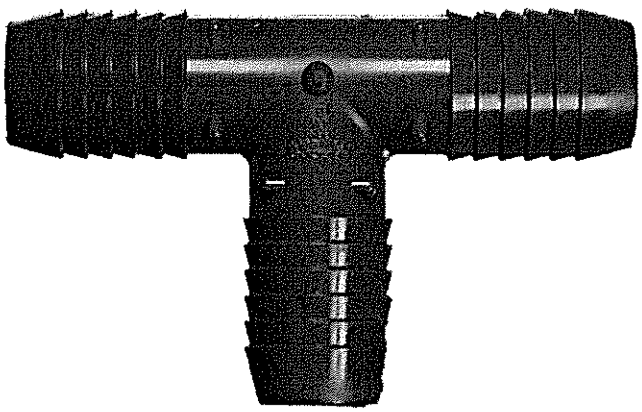


Figure 4: Image of a barbed insert tee or often commonly referred to as an insert tee. Note the ridges to aid in holding PE pipe in place with the use of a clamp.

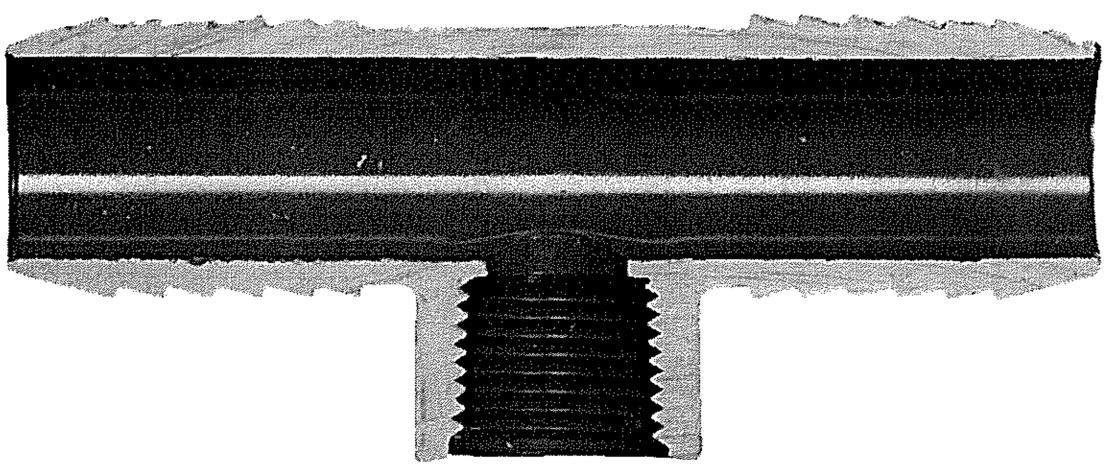


Figure 5: A combination or service tee. In this example, this is a 1" by ½" combination tee (Ins × Ins × FIPT).

PVC Compression Pressure Fittings

These fittings are for joining PVC plastic, HDPE, iron, steel, and copper pipe to each other. Since the cap and body are recessed for a compression sealing gasket, no fluid can enter the thread cavity of the cap, providing a duplex seal.

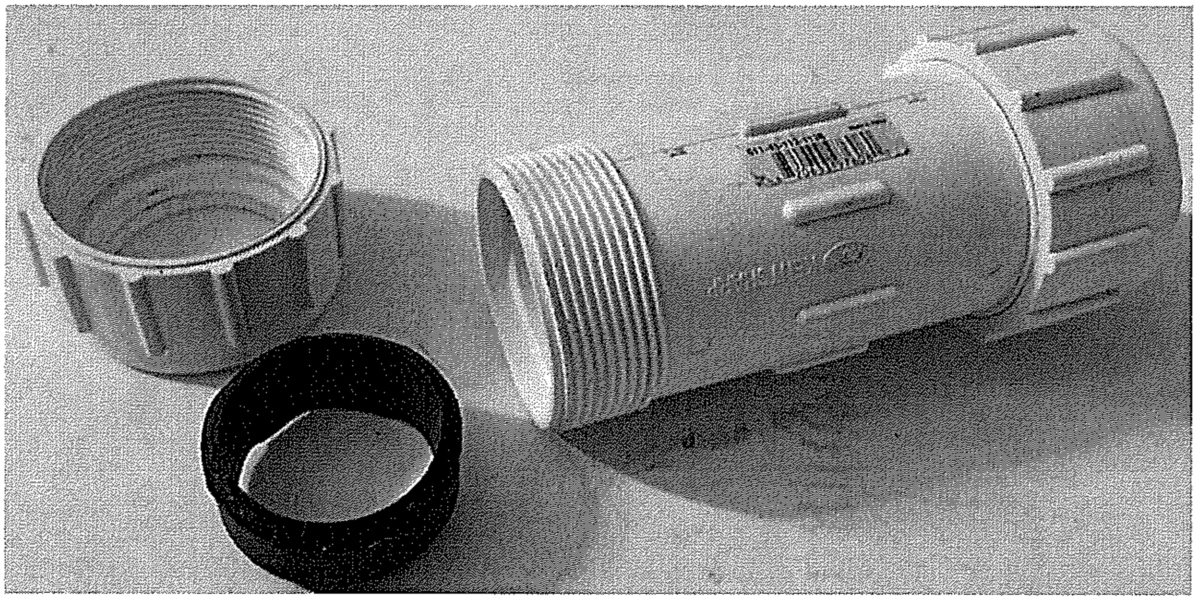


Figure 6: Compression pressure fitting — as the threaded cap tightens, it squeezes the O-ring and creates a seal against the pipe.

Compression pressure fittings:

- are leakproof, with no threading or cementing required
- make repairs or alterations in pipelines more convenient
- can be inserted between butted pipe ends, no clearance needed
- have a compressive action that creates a strong gripping action over a wide area of pipe
- resists longitudinal pull out

Slip Fix/Quick Fix Repair Couplings

Slip fix/quick fix repair couplings are an in-line PVC repair coupling (Figure 7.3.7). They can simplify repairing a broken line, installing a valve or adding a lateral or riser. To use these, you simply cut out the damaged pipe, drop in repair coupling and solvent weld for a tight permanent seal.

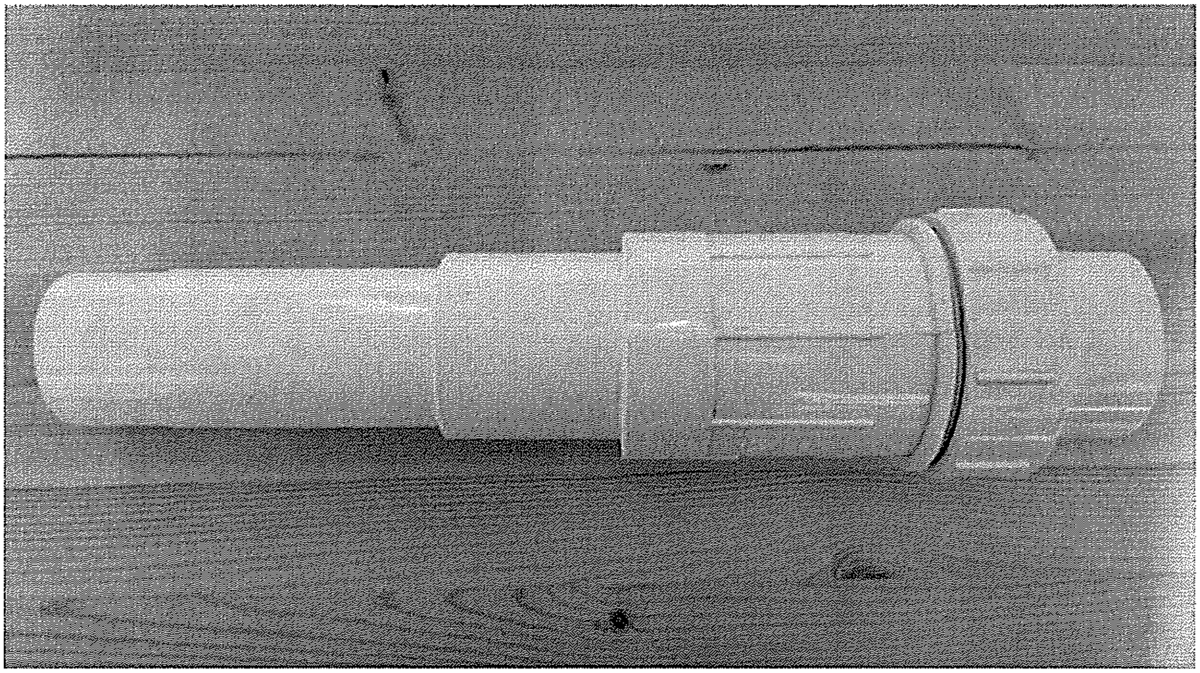


Figure 7: Slip fix/quick fix repair coupling. Have an internal O-ring seal that allows the coupling to telescope to meet multiple repair scenarios (this example is fully extended 3 inches (on the left)).

Slip fix/quick fix couplings:

- can shorten dig back for sections of pipe to repair lines
- are easy to install next to fittings where space is limited
- have an O-ring relief to assure a tight seal with no leaks
- require no bracing and has no nuts to tighten

ACME

ACME inlet threaded fittings have become the preferred thread configuration-type in the golf course irrigation market and is continuing to expand into other professional irrigation markets. An ACME thread has a flat apex and valley (Figure 8), and a wider tooth shape than an NPT thread (Figure 9). The wider tooth means it can withstand a greater load than a similarly sized square thread or IPT/NPT thread. An ACME thread also contains an O-ring to create a better seal.

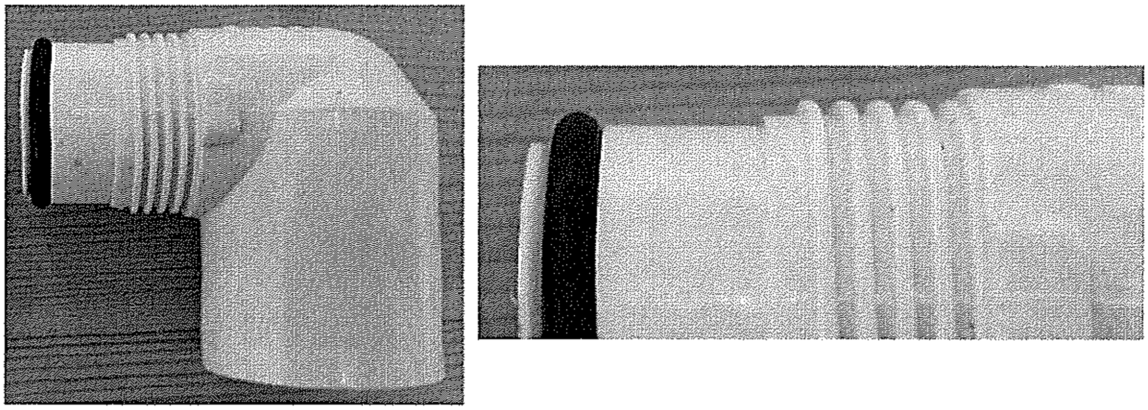


Figure 8: (left) ACME threaded fitting. (right) ACME fitting — flat apex and valley thread configuration with O-ring.

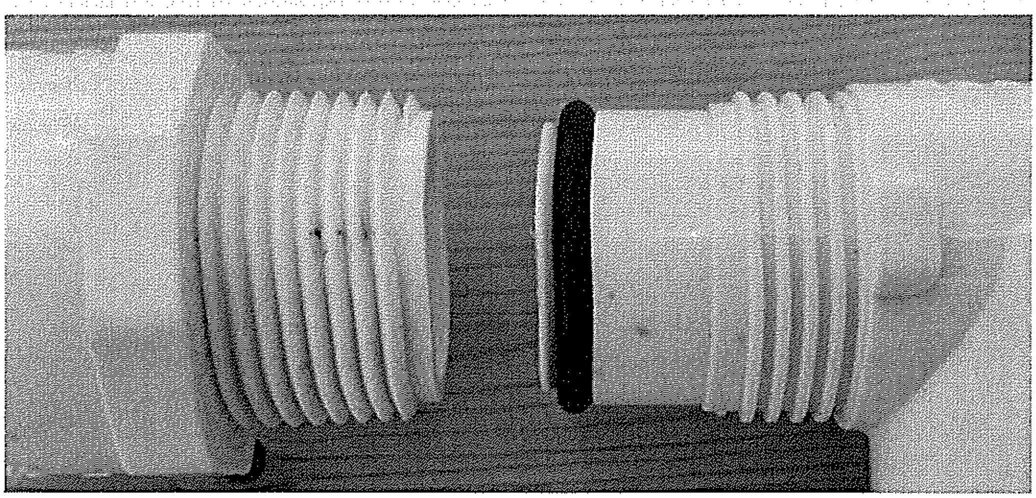


Figure 9: (left) IPT/NPT fitting - pointed apex and valley thread. (right) ACME fitting — flat apex and valley thread configuration with O-ring.

The ACME thread has a configuration that eliminates the "V" notch and provides clearance with all diameter piping while contributing high strength. The ACME thread is less sensitive to bending loads because there is no "V" notch. An added feature of the ACME style thread is that it provides "free" and "easy" movement up to proper engagement. This feature prevents the "stick," "lock" or "gall" which is common with PVC threaded parts.

When Installing ACME Threaded Fittings

It is recommended to hand tighten your fitting until it stops, then back off a half turn to allow free movement of the fitting. The O-ring maintains the seal while the threads provide joint strength.

Polypropylene Compression Pressure Fittings

These compression fittings are manufactured from lightweight high-performance thermoplastic materials which resist corrosion and can minimize maintenance, repairs, and long-term costs.

Figure 10: Polypropylene compression pressure fitting — this particular tee's connectors are intended for a 2-inch HDPE pipe. The nut connectors can be changed to connect to other types of pipe if needed (such as an ACME swing joint).

The materials have decent impact, UV, and chemical resistance. Polypropylene compression fittings are pressure rated to 230psi and can be used to transition to and from a number of different types of piping, including copper, PE, HDPE, PVC, lead, steel, galvanized steel, ABS, and stainless steel. They also have many connection points such as Socket (smooth pipe), IPT, and ACME.

They are relatively easy to connect and disconnect. When making a connection, what is needed is to tighten it until the nut does not require any reasonable force and the seal is made.

Saddles

In a PVC system, adding a sprinkler head, a branch, or a lateral often requires deconstructing large parts of the system. Saddles allow for a modification to be added without a major demolition (Figure 7.3.11). They simply clamp onto the outside of the pipe, then create a tee joint in an existing system. Once the saddles are firmly clamped into place, a small hole is drilled through the saddle top into the pipe, allowing flow without destroying the entire system or removing any major parts. This is often the simplest way to add a line to an existing irrigation system.

Credit: "PVC Saddle Clamp" by Alibaba and is used under Fair Use.

Figure 11: PVC saddle clamp.

Saddles can be installed into PVC, PE, and HDPE systems. As previously mentioned, the most common saddles are mechanically clamped to PVC and HDPE using nuts and bolts, but there are also saddles that are temporarily strapped or bolted and then fused thermoelectrically through the electrofusion process.

With electrofusion saddles (Figure 12), they are attached with bolts initially, but once the electrofusion process is completed, the bolts become redundant but can be left attached for additional support.

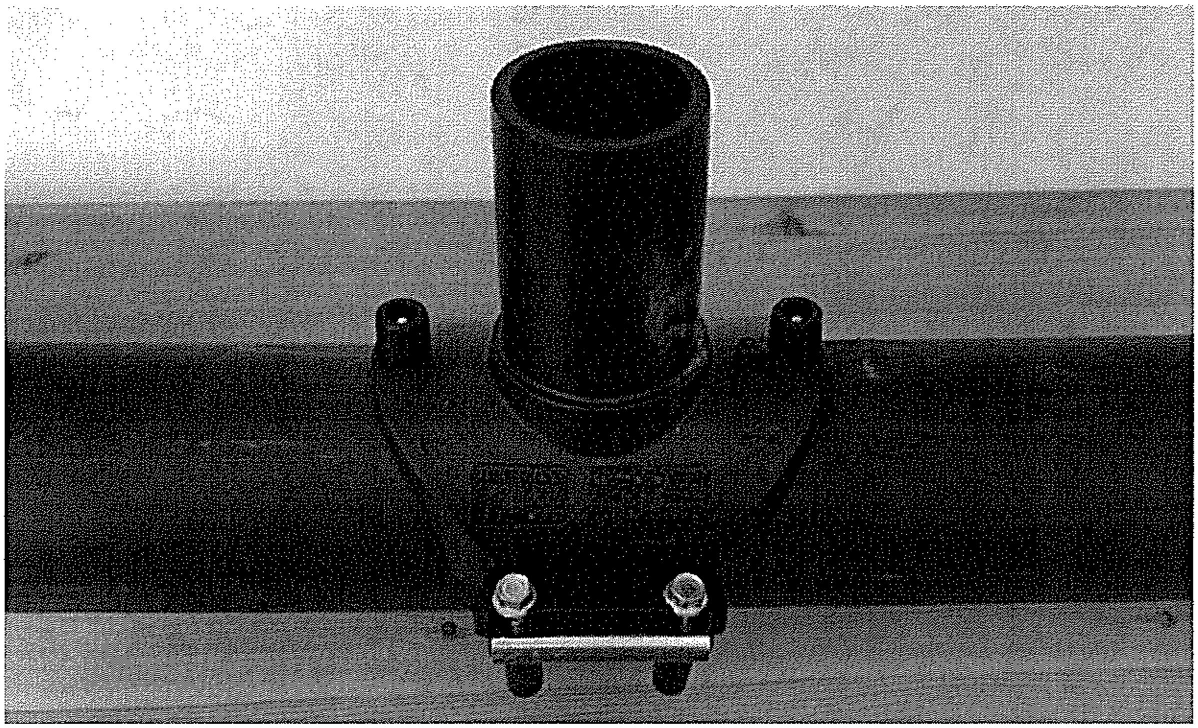


Figure 12: Electrofusion saddle with bolted clamp.

Pipe Nipples

Fundamentally, a nipple is a short length of pipe with male pipe threads at both ends for connecting other fittings. There is a short distance of unthreaded pipe between the two threaded ends, depending on how far apart you need the attached fittings to be.

Credit: "Pipe Nipple" by budgetmarine.com and is used under Fair Use.

Figure 13: PVC nipple pipe.

Please read this short article on nipple pipe as a pipe fitting.

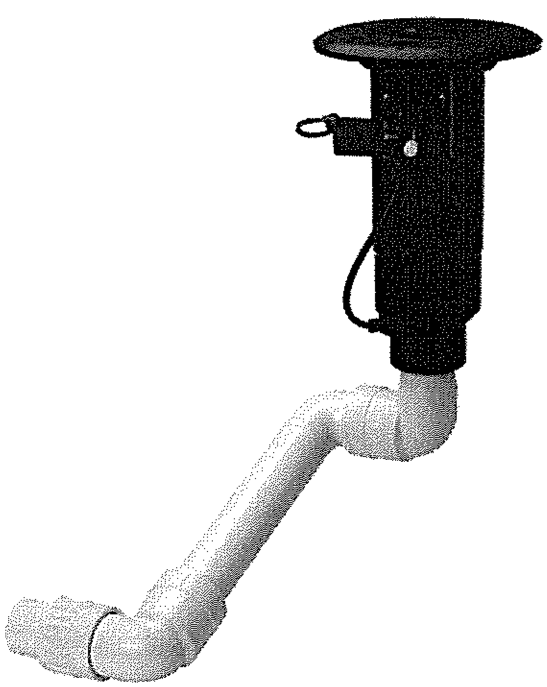
As stated in the article, when purchasing pipe nipple, the following characteristics need to be specified:

- Diameter
- Length
- Schedule
- Material
- End connections

Example: If you needed a 2-inch diameter nipple pipe, 8 inches long made of Schedule 40 PVC, you may say, "I need a 2-inch by 8-inch nipple pipe, Schedule 40, PVC" (or you may even simpler just say, "I need a 2x8 nipple, Schedule 40 PVC"). In irrigation, it would be extremely rare to have the thread type be anything other than **threaded both ends (TBE)**, so that part is predominantly assumed, unless of course, you did require something else.

Swing Joints

Before we finish the fittings section, this is a good time to revisit the connection between the buried pipelines and the sprinklers they connect to the piping system. Every sprinkler should be installed flush with the soil surface and the sprinkler should be vertical in orientation. The pipe used to connect the supply line to the sprinkler should be a rather complex collection of short pieces of pipe and elbows designed to locate the sprinkler properly with regard to the supply pipe.



Credit: "Swing Joints" by Toro and is used under Fair Use.

Figure 14: Pre-manufactured swing joint. Swing joints can also be custom made with individual pipe and fittings.

These connections are usually called swing joints (Figure 14). Note that the connection to the supply pipe is almost always horizontal from the side of the pipe. After the first 90-degree elbow a second pipe section parallels the supply pipe and rises toward the sprinkler. Then a second 90-degree elbow to a third pipe section carries the flow away from the supply pipe. The goal here is to locate the sprinkler to one side of the supply pipe. Note some installations reverse the direction of this second elbow to place the sprinkler directly over the supply pipe. In this case, you know the pipe is always just below the sprinklers. Finally, a third 90-degree elbow connects to a short nipple that connects to the sprinkler. The four short pipe sections in the swing joint and the entry threads at the base of the sprinkler should all be the same diameter.